

Evaluation of Project Processes in Relation to Transportation System Management and Operations (TSM&O)



FDOT Contract No. BDV34-977-07

Prepared for:



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Final Report

January 2018

DISCLAIMER

The opinions, findings, and conclusions, expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Evaluation of Project Processes in Relation to Transportation Systems Management and Operations (TSM&O)		5. Report Date January 2018	
		6. Performing Organization Code	
7. Authors: Sando, T., Alluri, P., Hagen, L., Angel, M., and Saha, D.		8. Performing Organization Report No.	
9. Performing Organization Name and Address University of North Florida 1 UNF Drive Jacksonville, FL 32224		10. Work Unit No.	
		11. Contract or Grant No. BDV34-977-07	
12. Sponsoring Agency Name and Address Florida Department of Transportation Research Center 605 Suwannee Street, MS 30 Tallahassee, FL 32399		13. Type of Report and Period Covered Final Report January 2016 to January 2018	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract This study was conducted to explore the current state-of-the-practice of Transportation Systems Management and Operations (TSM&O) in the Florida Department of Transportation (FDOT) and determine what would be required to mainstream TSM&O throughout the project development process. A comprehensive review of existing FDOT guidelines, two statewide surveys, and a review of projects that may serve as case studies, where a TSM&O strategy was identified as the preferred alternative or solution to address a capacity or safety issue, were studied to determine the extent to which TSM&O is currently being incorporated in FDOT projects. An additional survey was also conducted to explore TSM&O best practices used by other state DOTs. Alternative project development, procurement, and budgeting options for ITS and TSM&O projects were also explored. Based on the information gathered from the aforementioned efforts, suggested recommendations to mainstream TSM&O throughout the project development process include: provide education and understanding of TSM&O in all disciplines; require communication and coordination with TSM&O staff in all project phases; develop a formalized process and procedure for TSM&O inclusion; and provide supportive TSM&O language in Department guidelines. Suggested recommendations to consider while procuring, budgeting, and developing software-related ITS and TSM&O projects include: consider adopting the Agile method for developing applicable TSM&O/ITS projects; consider a two-phase development process using the Agile approach for Phase I and the Waterfall approach for Phase II; include the end users of the system throughout the project development process; incorporate TSM&O/ITS best practices into contract templates; and train applicable FDOT staff in Agile principles.			
17. Key Word Transportation Systems Management & Operations (TSM&O), Intelligent Transportation Systems (ITS), State-of-the-practice		18. Distribution Statement No restrictions.	
19. Security Classif. (of this report) Unclassified.	20. Security (of this page) Unclassified.	21. No. of Pages 339	22. Price

ACKNOWLEDGEMENTS

The authors would like to thank the Florida Department of Transportation (FDOT) Project Managers and staff that participated in this research effort. Their time and assistance are greatly appreciated.

Central Office: Raj Ponnaluri

District 1: Katherine Chinault, Mark Mathis, Mark Robert, and Steve Miller

District 2: Peter Vega, Josh Ryker, Matt Harper, Karen Taulbee, and Justin Ryan

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EXECUTIVE SUMMARY

As the population increases, the demands placed on existing infrastructure by an increasing number of road users have prompted transportation agencies to consider alternative solutions to improve highway safety and mobility. Consequently, Transportation Systems Management and Operations (TSM&O) programs have become a central part of many transportation agencies. Florida is no exception, as efforts are underway by the Florida Department of Transportation (FDOT) to mainstream TSM&O throughout the FDOT's project development processes and procedures.

This study explored the current state-of-the-practice of TSM&O at the FDOT to determine what would be required to mainstream TSM&O throughout the project development process. The objectives of this research effort included:

1. Conduct a comprehensive review aimed at providing recommendations that would facilitate revisions of the existing methods to better accommodate TSM&O in the project development process.
2. Explore and recommend alternative project development, procurement, and budgeting options for Intelligent Transportation Systems (ITS) and TSM&O projects.

A comprehensive review of existing FDOT guidelines, two districtwide surveys, and a review of projects that may serve as case studies, where a TSM&O strategy was identified as the preferred alternative or solution to address a capacity or safety issue, were studied to determine the extent to which TSM&O is currently being incorporated in FDOT projects. An additional survey was also conducted to explore TSM&O best practices used by other state DOTs.

The objective of the guidelines review was to identify the degree to which TSM&O directives are included or referenced in the current FDOT procedural and design guidelines. The initial review of FDOT guidelines was conducted in July 2016. However, significant revisions related to TSM&O occurred with several publications prompting a second review of the documents. Findings from the second review, reflecting these changes, are discussed in Chapter 3 of the report.

The objective of the districtwide surveys was to gather information on the current state-of-the-practice of TSM&O in each of the eight FDOT Districts, including the Florida Turnpike Enterprise (FTE). The first survey was administered to project managers in the TSM&O, ITS, and Traffic Operations groups in July 2016. The second survey was administered in December 2016 to project managers and staff from other areas, such as design, planning, Project Development & Environment (PD&E), and construction. An additional survey was administered to DOT TSM&O/ITS and Traffic Operations staff in each state in the U.S, including Florida, in April 2016, to explore best practices used in their TSM&O implementation methods.

Projects identified by project managers in the first districtwide survey were also examined to serve as case studies to provide examples of TSM&O strategies deployed in Florida, as well as challenges encountered and lessons learned during each project.

Based on information gathered from the aforementioned research tasks, suggested recommendations to facilitate the mainstreaming of TSM&O throughout the FDOT include:

- Provide education and understanding of TSM&O in all disciplines
- Require communication and coordination with TSM&O staff in all project phases
- Develop a formalized process and procedure for TSM&O inclusion
- Provide supportive TSM&O language in FDOT guidelines

Additional requirements for mainstreaming TSM&O include:

- Improve the overall culture of TSM&O in the FDOT
- Place greater importance on TSM&O through policy and procedure
- Encourage the sharing of knowledge of TSM&O strategies and products
- Develop an outreach program for potential contractors and inspectors
- Consider a certification program for Construction Engineering & Inspection (CEI) contractors
- Allow TSM&O staff more input with accepting or rejecting construction work

TSM&O projects are performance-based, and consist of not only ITS strategies, but also other reliability and safety strategies, such as hard-shoulder running and signing and marking modifications. However, the majority of TSM&O projects contain ITS technologies, and as a result, are increasingly software-based. These types of TSM&O projects are referred to as “TSM&O/ITS” projects in this report.

Project development, procurement, and budgeting options for TSM&O/ITS projects were also explored. As a first step, the existing project development processes were identified and documented. A survey was conducted to obtain information regarding specific challenges and shortfalls of the current project development process undertaken for district- and state-level ITS, Advanced Traffic Management Systems (ATMS), and TSM&O projects. The project managers for the Operations Task Manager (OTM), Integrated Corridor Management System (ICMS), and Maintenance Information Management System (MIMS) projects were surveyed.

Alternative project development approaches, including the Agile framework, were explored to see if they could be adopted for TSM&O/ITS projects, especially for those projects that evolve as the project progresses. Unlike the traditional Waterfall approach, Agile methodology is a faster paced approach that is more value-driven, change-oriented, and collaborative. Agile methodology adapts to changing requirements, encourages active participation of users, stakeholders, and customers, and ensures quick completion. Scrum, the most popular approach of Agile methodologies, offers an iterative, incremental approach to optimize predictability and

manage risk. Agile methodologies, if adopted for software-based projects, will result in a product that is developed within budget and on-time, and meet the expectations of the stakeholders. Suggested recommendations pertaining to project development, procurement and budgeting options for software-related TSM&O/ITS projects include:

- Consider adopting the Agile method for developing applicable software-related TSM&O and ITS projects
- Consider a two-phase development process using the Agile approach for Phase I, and the Waterfall approach for Phase II for software-related TSM&O/ITS projects.
- Include the end users of the system throughout the project development process
- Incorporate TSM&O/ITS best practices into contract templates
- Train applicable FDOT staff in Agile principles

The transportation industry is becoming more technologically advanced each year. With a strong commitment to developing the TSM&O program and placing a greater importance on TSM&O, implementation of suggested recommendations discussed in this report can facilitate the effective mainstreaming of TSM&O throughout the FDOT project development process.

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ACRONYMS

AAM	Active Arterial Management
AASHTO	American Association of State Highways and Transportation Officials
ALDOT	Alabama Department of Transportation
AMPM	Active Management Payment Mechanism
AMS	Arterial Management System
APL	Approved Product List
APTS	Advanced Public Transit Systems
ARTIMIS	Advanced Regional Traffic Interactive Management and Information System
ASCT	Adaptive Signal Control Technology
ATCS	Adaptive Traffic Control Systems
ATDM	Active Transportation and Demand Management
ATIS	Advanced Traveler Information Systems
ATM	Active Traffic Management
ATMS	Advanced Traffic Management Systems
ArTMS	Arterial Traffic Management Systems
B/C	Benefit-Cost
BOM	Build-Operate-Maintain
BOS	Bus on Shoulder
BRT	Bus Rapid Transit
CADD	Computer Aided Design and Drafting
Caltrans	California Department of Transportation
CCTV	Closed Circuit Television
CDOT	Colorado DOT
CEI	Construction Engineering & Inspection
CFR	Code of Federal Regulations
CHART	Coordinated Highways Action Response Team
CMAQ	Congestion Mitigation and Air Quality Improvement
CMM	Capability Maturity Model
CMP	Congestion Management Process
COA	Class of Action
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CPAM	Construction Project Administration Manual
CPPR	Contractor Past Performance Rating
CSMP	Corridor System Management Plan
CUTR	Center for Urban Transportation Research
CVAV	Connected Vehicle Automated Vehicle
CVO	Commercial Vehicle Operations
D1	FDOT District One
D2	FDOT District Two
D3	FDOT District Three
D4	FDOT District Four

D5	FDOT District Five
D6	FDOT District Six
D7	FDOT District Seven
DB	Design-Build
DB[OM]	Design-Build (Operate and Maintain)
DBOM	Design-Build-Operate-Maintain
DCPME	District Consultant Project Management Engineer
DelDOT	Delaware Department of Transportation
DFE	Data Fusion Environment
DMS	Dynamic Message Signs
DOT	Department of Transportation
DPS	Department of Public Safety
DSS	Decision Support System
DTOE	District Traffic Operations Engineer
DWL/DL	Deficiency Warning Letter/ Deficiency Letter
EIS	Environmental Impact Statement
EL	Express Lanes
ERC	Electronic Review Comments
EST	Environmental Screening Tool
ETAT	Environmental Technical Advisory Team
ETDM	Efficient Transportation Decision Making
FDM	Florida Design Manual
FDOT	Florida Department of Transportation
FEIS	Final Environmental Impact Statement
FHP	Florida Highway Patrol
FHWA	Federal Highway Administration
FIDG	Florida Intersection Design Guide
FITSEVAL	Florida Intelligent Transportation Systems Evaluation Tool
FLPO	Freight Logistics and Passenger Operations
FMS	Freeway Management System
FSUTMS	Florida Standard Urban Transportation Model Structure
FTE	Florida Turnpike Enterprise
FTMS	Freeway Traffic Management System
FTP	Florida Transportation Plan
GEC	General Engineering Consultant
HAR	Highway Advisory Radio
HBC	Highway/Bridge Construction
HOT	High Occupancy Toll
HOV	High Occupancy Vehicle
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
ICM	Integrated Corridor Management
ICMS	Integrated Corridor Management System
IDAS	ITS Deployment Analysis System
I/D	Incentives/Disincentives

ID/IQ	Indefinite Delivery/Indefinite Quantity
IEN	Information Exchange Network
IJR	Interchange Justification Request
IMC	Intersection Movement Counts
IMR	Interchange Modification Request
IMS	Incident Management System
ISD	Intermodal Systems Development
ISP	Internet Service Provider
IT	Information Technology
ITB	Invitation to Bid
ITN	Invitation to Negotiate
ITS	Intelligent Transportation Systems
IV&V	Independent Validation and Verification
LCIS	Lane Closure Information System
LOPP	List of Priority Projects
L RTP	Long Range Transportation Plan
M&O	Management and Operations
MAP-21	Moving Ahead for Progress in the 21 st Century
MDOT-SHA	Maryland DOT State Highway Administration
MIMA	Maintenance and Inventory Mobile Application
MIMS	Maintenance Information Management System
ML	Managed Lanes
MnDOT	Minnesota DOT
MOE	Measures of Effectiveness
MOT	Maintenance of Traffic
MPO	Metropolitan Planning Organization
N/A	Not Applicable
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NHPP	National Highway Performance Program
NHS	National Highway System
NJDOT	New Jersey DOT
NMSA	Non-Major State Action
NPV	Net Present Value
P3	Public-Private Partnership
PSEMP	Preliminary System Engineering Management Plan
OCIO	Office of the Chief Information Officer
OIT	Office of Information Technology
O&M	Operations and Maintenance
OTM	Operations Task Manager
OTO	Office of Traffic Operations
PCE	Programmatic Categorical Exclusion
PD&E	Project Development & Environment
PER	Preliminary Engineering Report
PM	Performance Measures
PMH	Project Management Handbook

PPM	Plans Preparation Manual
RCTO	Regional Concept for Transportation Operations
RFP	Request for Proposal
RISC	Rapid Scene Clearance
ROD	Record of Decision
ROW	Right-of-Way
RTMC	Regional Transportation Management Center
RWIS	Road Weather Information Systems
SAFETEA-LU	Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users
SCMEP	South Carolina Manufacturing Partnership
SE	System Engineering
SEIR	State Environmental Impact Report
SEMP	Systems Engineering Management Plan
SEP	Systems Engineering Process
SERF	System Engineering Review Form
SHS	State Highway System
SIRV	Severe Incident Response Vehicle
SIS	Strategic Intermodal System
SOM	System Operations and Management
SR	State Road
STP	Surface Transportation Program
SWAT	State-Wide Acceleration Transformation
TDM	Travel Demand Management
TDOT	Tennessee Department of Transportation
TEM	Traffic Engineering Manual
TERL	Traffic Engineering Research Laboratory
TIGER	Transportation Investment Generating Economic Recovery
TMC	Transportation Management Center
TOPS-BC	Tool for Operations Benefit-Cost Analysis
TPAS	Truck Parking Availability System
TPO	Transportation Planning Organization
TRIMMS	Trip Reduction Impacts of Mobility Management Strategies Model
TS2	Traffic Signal Type 2
TSM	Transportation Systems Management
TSM&O	Transportation Systems Management and Operations
TSP	Transportation System Plan
UPWP	Unified Planning Work Program
WWD	Wrong-Way Driving

1 - INTRODUCTION

Travel reliability and highway safety are of paramount importance to transportation agencies. As the population increases, the demands placed on existing infrastructure by an increasing number of road users have prompted agencies to consider alternative solutions to improve highway safety and mobility. Consequently, Transportation Systems Management and Operations (TSM&O) programs have become a central part of many transportation agencies. By definition, TSM&O is an integrated program to optimize the performance of existing multimodal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of the transportation system (Federal Highway Administration [FHWA], 2012a). Focus areas of TSM&O concentrate on the reduction of congestion and delay, thus providing a higher level of service and safety. TSM&O strategies for existing roadways include a variety of Management and Operations (M&O) solutions, such as active traffic and incident management, signal timing and coordination, ramp metering, roadway weather management, and travel information systems.

Although TSM&O strategies are gaining significance by providing more financially viable alternatives to address traffic demand, consideration of TSM&O in the highway planning and design process is often lacking. Typically, TSM&O components are included in the project development process as an afterthought, occurring well after capacity expansion measures. Moreover, TSM&O considerations in the work program development process may not always reflect important aspects such as operations, maintenance, and other practices. The extent to which TSM&O is included in planning processes, such as highway planning for Strategic Intermodal System (SIS) roadway networks or Long Range Transportation Plans (LRTP), established for local roadway networks, needs to be explored. Opportunities to better coordinate the planning process and operational activities may be realized. Furthermore, linking planning and operations may potentially result in optimal designs and eliminate redundant ad hoc activities that could be integrated into minor or major projects. Design decisions, such as type of mast arm, type of signal system, provisions for fiber optics, Bluetooth installations, etc., made during the planning phase may reduce the number of TSM&O special projects aimed at operational and maintenance activities, as well as reduce the overall cost of TSM&O implementation in the future.

Since roadway improvement funding is inherently limited, it is practical to consider TSM&O strategies as alternative solutions to address congestion and safety. The objective of this project is to determine gaps in the project development process in Florida and recommend revisions to the state-of-the-practice to better accommodate TSM&O components in roadway projects.

To determine the extent to which TSM&O is currently being incorporated in Florida Department of Transportation (FDOT) projects, research was conducted and involved a comprehensive review of existing FDOT guidelines, two districtwide surveys, and a review of projects, that may serve as case studies, where a TSM&O strategy was identified as the preferred alternative or

solution to address a capacity or safety issue. An additional survey was also conducted to explore TSM&O best practices used by other state DOTs.

The objective of the FDOT guidelines review was to identify the degree to which TSM&O directives are included or referenced in the current FDOT procedural and design guidelines. Findings from this exercise are discussed in chapter three of this report.

The objective of the Districtwide surveys was to gather information on the current state-of-the-practice of TSM&O in each of the eight FDOT Districts, including the Florida Turnpike Enterprise (FTE). The first survey, reported in chapter four, was administered to project managers in the TSM&O, Intelligent Transportation Systems (ITS), and Traffic Operations groups in July 2016. The second survey, reported in chapter five, was administered in December 2016 to project managers and staff from other areas, such as design, planning, Project Development & Environment (PD&E), and construction. An additional survey was administered to DOT TSM&O/ITS and Traffic Operations staff in each state in the U.S, including Florida, in April 2016, to explore best practices used in their TSM&O implementation methods (chapter six).

Projects identified by project managers in the first Districtwide survey were also examined to serve as case studies to provide examples of TSM&O strategies deployed in Florida, as well as challenges and lessons learned encountered during each project. These findings are reported in chapter 10.

Chapters seven through nine focus on evaluating and recommending suitable project development, procurement, and budgeting options for ITS and TSM&O projects. As a first step, the existing project development processes were identified and documented. A survey was conducted to obtain information regarding specific challenges and shortfalls of the current project development process undertaken for district- and state-level ITS, ATMS, and TSM&O projects. The project managers for the Operations Task Manager (OTM), Integrated Corridor Management System (ICMS), and Maintenance Information Management System (MIMS) projects were surveyed. Survey findings are reported in chapter seven of this report.

Alternative project development approaches, including the *Agile* framework, were explored to see if they could be adopted for ITS and TSM&O projects (chapter eight). The most suitable procurement and budgeting options for software-related ITS and TSM&O projects that adopt *Agile* principles are discussed in chapter nine.

Chapter 11 briefly discusses findings from the aforementioned research tasks and offers suggested recommendations to facilitate the mainstreaming of TSM&O throughout the FDOT.

2 – LITERATURE REVIEW

Over the past decade, the importance of linking planning and operations in the project development process has slowly emerged. Initial source material published by the Federal Highway Administration (FHWA) (2004) emphasized regional partnerships and building stronger linkages between planning and operations within Metropolitan Planning Organizations (MPO). A later primer was released to promote cooperative relationships between the planning and operations divisions of State Departments of Transportation (DOTs) (FHWA, 2008). The report was targeted at DOT planning and operations staff to raise awareness of the opportunities in addressing roadway congestion, especially non-recurring forms, such as traffic incidents, work zones, inclement weather, and special events (FHWA, 2008).

Building on transportation programs and policies established in 1991, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law in July 2012, expanding the National Highway System (NHS) and routing more than half of federal highway funding to a new program, the National Highway Performance Program, to institute national goals for performance and outcome-based surface transportation projects (MAP-21, 2012). To meet the requirements set forth by MAP-21 for enhancements to safety, infrastructure condition, congestion reduction and system reliability, the FHWA published a primer report in 2013 discussing TSM&O strategies used in various modes of transportation (FHWA, 2013). Although the report emphasized the effectiveness of linking planning activities to operations initiatives, at both the State and metropolitan levels, the primary focus was on TSM&O consideration during the design phase of the project development process, such as bus and express lanes, median crossovers, bus turnouts, and emergency access between interchanges, all of which help to facilitate operations efforts at a later date.

A later report by Jin et al. (2014) focused on linkage opportunities between planning and operations. However, the research primarily concentrated on regional-level operations measures involving cross-jurisdictional integration approaches. A number of literature sources were reviewed, reflecting over of a decade of interest in integrating operations early in the project development process. The majority of source material relates to the regional concept for transportation operations (RCTO), the Congestion Management Process (CMP), and regional Intelligent Transportation Systems (ITS). Although available, fewer source materials exist for Managed Lane (ML) guidelines, Active Transportation and Demand Management (ATDM) and Performance Measures (PM). In contrast, only one document, related to TSM&O application guidelines, was referenced - the FHWA (2013) primer report. Interestingly, many of these operation elements essentially fall under the umbrella of TSM&O.

An earlier primer released by the FHWA sought to provide guidelines for improving TSM&O activities on the State and local levels by introducing the capability maturity approach, a framework adapted from the Capability Maturity Model (CMM) concept developed in the Information Technology (IT) industry and modified for the transportation industry (FHWA, 2012a). The CMM approach identifies key areas that impact the effectiveness of a TSM&O

program from the business processes, systems and technology, performance measurement, culture, organization and workforce, and collaboration (FHWA, 2012a).

TSM&O encompasses a wide range of M&O strategies for surface infrastructure. Table 2.1 lists management strategies associated with M&O for freeways, arterials, signalized intersections, managed lanes, and parking.

Table 2.1: TSM&O Strategies

M&O Area	Management	Incident Management	Work zone Management	Transit Management Operation	Freight Management	Travel Demand Information	Travel Weather Management
Freeway	<ul style="list-style-type: none"> • Ramp metering • Dynamic message sign • CCTV • WWD detectors • Hard shoulder running • Variable speed signs • Overlane control signs • Connected vehicles 	<ul style="list-style-type: none"> • Warning signs • Crash staging areas • Road rangers • RISC • SIRV • Safe tow • Overlane control Signs 	<ul style="list-style-type: none"> • Illuminator • Speed limit • Variable speed signs 	<ul style="list-style-type: none"> • Shoulder bypass 	<ul style="list-style-type: none"> • Truck identification sensors • Truck classification sensors • CVO systems 	<ul style="list-style-type: none"> • Variable message signs • Overlane control signs • Smart-phone applications • Connected vehicles • BlueTOAD devices 	<ul style="list-style-type: none"> • Wind sensor/ anemometer • Weather information system • Visibility sensors • Rain sensors
Arterial	<ul style="list-style-type: none"> • Dynamic message signs • CCTV • Bluetooth • TS2 detection • Adaptive signals • Collision avoidance system • Integrated corridor management 	<ul style="list-style-type: none"> • Safe walk sensors • Safe tow • SIRV • Road rangers • Traffic signal preemption 	<ul style="list-style-type: none"> • Illuminator • Speed limit • Dynamic detouring 	<ul style="list-style-type: none"> • BOS lane signs • Queue jumps • Transit signal priority • BRT • Community shuttles • Smart phone applications 	<ul style="list-style-type: none"> • Trailblazer sign • BlueTOAD • Adaptive systems • Collision avoidance • Smart Phone applications 	<ul style="list-style-type: none"> • Variable message signs • Smart-phone applications • Connected vehicles 	<ul style="list-style-type: none"> • Weather information system • Rain sensors
Signalized Intersection	<ul style="list-style-type: none"> • CCTV • Safe walk sensors • Pedestrian sensors • Bicycle sensors • Smart phone applications 	<ul style="list-style-type: none"> • CCTV 	<ul style="list-style-type: none"> • Warning signs 	<ul style="list-style-type: none"> • Queue jumps • Transit signal priority • Downstream stops 	<ul style="list-style-type: none"> • Collision avoidance systems • Adaptive technology 		
Managed Lanes	<ul style="list-style-type: none"> • Gates • CCTV • Information board • Wrong way detection • Vehicle detection • Delineation 				<ul style="list-style-type: none"> • Electronic payment • Gate 		
Parking	<ul style="list-style-type: none"> • Information board • Electronic payment • Parking meter • Sensors • Smart-phone applications • Advanced reservation 				<ul style="list-style-type: none"> • Gate 		

2.1 Project Development State-of-the-Practice

In Florida, the project development process generally follows the path shown in Figure 2.1. Proposed projects originate from various sources: citizens groups, MPOs, rural counties, the FDOT, as well as the Florida State Legislature. MPOs generate a Long Range Transportation Plan (LRTP), followed by an annual List of Priority Projects (LOPP) outlining transportation needs in urban areas, while rural counties only develop an annual LOPP. Examples of projects originating from the FDOT include Feasibility Studies, Corridor Studies, Interstate Master Plans, Interchange Modification Requests (IMRs), and Interchange Justification Requests (IJRs). All proposed projects are vetted for purpose, need, and feasibility by FDOT in conjunction with other agencies and related authorities. Viable projects then enter the planning phase using the Efficient Transportation Decision Making (ETDM) process to bridge potential stakeholders and further qualify a project's viability (Florida Department of Transportation [FDOT], 2015a). The FDOT project development and environment (PD&E) phase follows the vetting process to address socioeconomic and environmental factors, as well as preliminary engineering and public involvement (FDOT, 2015b). Guidelines that promote compliance with all Federal and State laws, as well as design uniformity are provided in the FDOT PD&E Manual (FDOT, 2015b).

Final design, right-of-way (ROW) acquisition, and permitting precede the culmination of the process, the construction phase. For the majority of transportation projects, the process ends upon the completion of construction with operation efforts, such as Management & Operations (M&O), occurring at a future date when the need is realized. A preliminary review of the project development process in other states indicate similarities to the process used in Florida.

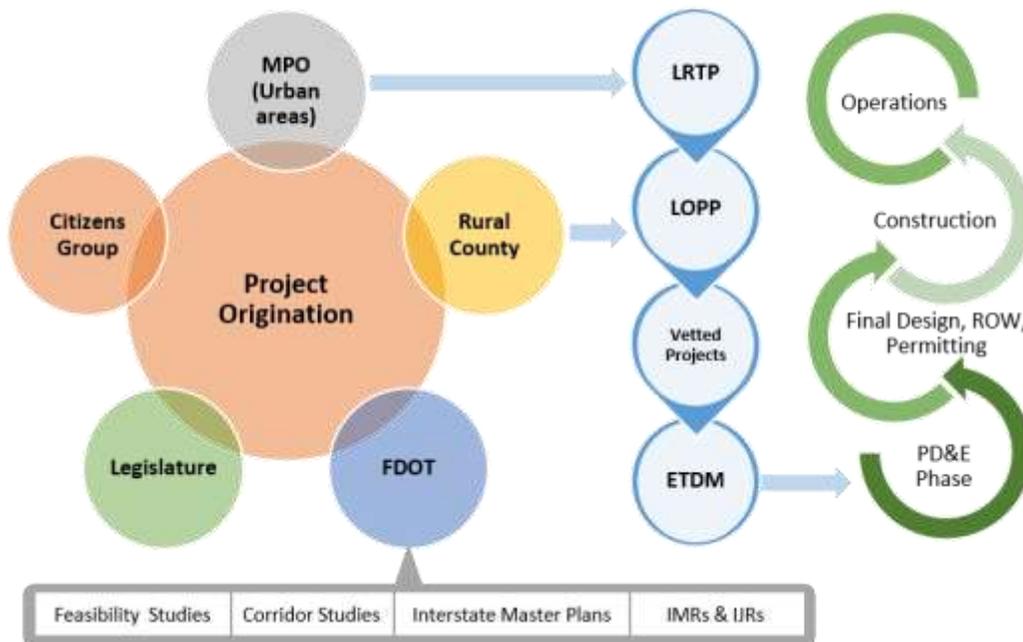


Figure 2.1: Transportation Project Development Process in Florida.

Project development guidelines published by the FDOT for State Highway System (SHS) projects are listed in Table 2.2. These documents were reviewed (Chapter 3) to determine the degree that TSM&O is considered and to identify gaps between typical project provisions and components of TSM&O strategies.

Table 2.2: FDOT Project Development Publications

FDOT Publication	Project Development Phase	Purpose
Computer Aided Design and Drafting (CADD) Manual	<ul style="list-style-type: none"> • Design 	<ul style="list-style-type: none"> • Engineering plans CADD production criteria • Requirements for electronic delivery of project plans
Design Standards	<ul style="list-style-type: none"> • Design 	<ul style="list-style-type: none"> • Roadway, Structure, and Drainage design elements • ITS design elements • Traffic Signals and Equipment
Efficient Transportation Decision Making (ETDM) Manual	<ul style="list-style-type: none"> • Planning • Environmental Assessment 	<ul style="list-style-type: none"> • Review of qualifying transportation projects • Early input of environmental considerations • Early identification of potential issues
Florida Intersection Design Guide (FIDG)*	<ul style="list-style-type: none"> • Intersection design 	<ul style="list-style-type: none"> • At-grade intersection requirements • Guide to identify and recommend appropriate solutions to intersection issues
Florida’s ITS Integration Guidebook	<ul style="list-style-type: none"> • Planning • Design • Operations 	<ul style="list-style-type: none"> • ITS integration process and related information
Florida Greenbook	<ul style="list-style-type: none"> • Design 	<ul style="list-style-type: none"> • Minimum standards and criteria
Plans Preparation Manual (PPM)*	<ul style="list-style-type: none"> • Design 	<ul style="list-style-type: none"> • Design criteria and process • Plans preparation and assembly
Practical Design Handbook	<ul style="list-style-type: none"> • Design 	<ul style="list-style-type: none"> • Performance based design • Practical Design approach
Project Development and Environment (PD&E) Manual	<ul style="list-style-type: none"> • Planning • Environmental Assessment • Preliminary Engineering 	<ul style="list-style-type: none"> • Approval of Environmental Document
Project Management Handbook	<ul style="list-style-type: none"> • Management 	<ul style="list-style-type: none"> • Management issues • Phase-specific management
Traffic Engineering Manual (TEM)	<ul style="list-style-type: none"> • Design • Operations 	<ul style="list-style-type: none"> • Traffic engineering criteria and standards
Work Program Instructions	<ul style="list-style-type: none"> • Work program development 	<ul style="list-style-type: none"> • Guidelines for the development of the work program

*Guidelines incorporated into the Florida Design Manual (FDM) released in 2018

2.2 TSM&O State-of-the-Practice

2.2.1 Florida

Recognizing a growing need for mobility and safety on Florida roadways, the FDOT formed TSM&O Leadership and Task teams in 2010, and moved toward a formal TSM&O Program with the development of a TSM&O strategic plan in 2013 (FDOT, 2013c). Recently, a more comprehensive statewide TSM&O strategic plan has been established (FDOT, 2017a). The mission of the program is “to identify, prioritize, develop, implement, operate, maintain, and update TSM&O program strategies and measure their effectiveness for improved safety and mobility.”

Currently, TSM&O strategies are at various levels of implementation in each of the FDOT’s seven districts, and the FTE. While Florida is moving forward with Active Traffic Management (ATM), Integrated Corridor Management (ICM), and connected vehicle initiatives, additional target TSM&O actions and strategies have been identified as listed in Table 2.3 (FDOT, 2013c). Traveler information systems, such as dynamic messaging signs (DMS) using integrated ITS technologies, have been a predominant management tool used statewide for many years.

Table 2.3: Target TSM&O Actions and Strategies (Source: FDOT, 2013c)

Focus Area	Benefit	Status
Ramp Signals	Regulates flow of traffic entering freeway	Implemented District 6 Guidance under development
Advanced Traffic Management System (ATMS)	Enhances signal coordination	Implemented statewide
Severe Incident Response Vehicles	Central point of contact at major incidents	Implemented Districts 4 and 6
Managed Lanes	Road managed in response to changing condition, creating a more effective and efficient freeway	Implemented District 6 Guidance under development
Incident Management	Improves safety for motorists and responders, reduces congestion, improves safety	Implemented statewide
Rapid Incident Scene Clearance	Heavy wrecker performance-based contract for major incidents	Statewide program available for implementation in Districts
Traveler Information	Improved traveler decision-making in response to changing conditions	Implemented statewide
Arterial Management	More effectively manage traffic on arterial roadways	Implemented Districts 1, 2, 4, and 6 <i>Statewide Needs Plan</i> in development [focus on intersection operations]
Work Zone Traffic Management	Improved safety and enhanced traffic management in work zones	Under development statewide

Table 2.3: Target TSM&O Actions and Strategies (continued) (Source: FDOT, 2013c)

Focus Area	Benefit	Status
Weather Information	Advanced information for significant weather events and changing conditions	Under development statewide
Variable Speed Limits	Uniform Traffic Flows	Implemented District 5
Hard Shoulder Running	Corridor Management	Guidance under development

Significant efforts to mainstream TSM&O throughout all aspects of the project development process have occurred over the last year (FDOT, 2017a). These efforts aim to bridge the gap between planning and operations, and promote FDOT policy and culture to provide efficient and safe travel for Florida motorists through TSM&O strategies. Presently, cooperative efforts between FDOT planning and operations divisions vary statewide.

2.2.2 Other States

TSM&O practices have been implemented at various levels in other states. The California DOT (Caltrans) frequently evaluates heavily traveled corridors and develops Corridor System Management Plans (CSMP) to address bottlenecks using M&O strategies for both recurring and non-recurring sources of congestion (FHWA, 2013). Pennsylvania and Missouri DOT have integrated operational considerations, to some degree, into design and policy guidelines (FHWA, 2013). Washington DOT is also working to implement operational solutions in the design process through a System Operations and Management (SOM) Committee consisting of topic-related members, including planning, throughout the state.

Nevada has implanted policies and procedures requiring all projects to be designed to meet Regional ITS architecture standards, and the consideration of installing conduit if future traffic signals may be warranted (FHWA, 2013). A review of M&O requirements is conducted by the Delaware Department of Transportation (DelDOT) in the design phase of transportation projects (FHWA, 2013). Additionally, capacity expansion projects must also include a list of supplemental strategies in compliance with the Delaware Valley Regional Planning Commission congestion management process (FHWA, 2013).

Alabama Department of Transportation (ALDOT) is moving forward with both statewide and regional TSM&O initiatives following the CMM approach (ALDOT, 2015). Current capabilities of ALDOT's operation system, ALGO, include event management, detection, verification and notification, and performance reporting. Additionally, ALDOT recently launched a traveler information website (ALGOtraffic.com), providing up-to-the minute traffic information, road conditions, and work zone updates (ALDOT, 2015).

2.3 TSM&O Project Procurement and Contract Execution Processes

This section focuses on innovative project delivery systems, procurement practices, and contract management methods that could potentially be adopted for TSM&O projects. Some of the system development strategies (i.e., models) that could be adopted for TSM&O and ITS projects are also discussed. Finally, potential funding sources for TSM&O projects are listed.

2.3.1 Project Delivery Systems

Project delivery systems refer to the overall processes by which a project is designed, constructed, and/or maintained. TSM&O projects could benefit from considering more innovative approaches which could potentially improve the speed and efficiency of the project delivery process. The following are some of the methods that could potentially be adopted for TSM&O projects (Trauner Consulting Services, Inc., 2007):

- *Design-Build*: A project delivery system involving a single contract between the project owner and a design-build contractor covering both the design and construction of a transportation project. A *design-build* contract may also include responsibilities that extend beyond the design and construction phases of a project, including:
 - *Design-Build-Warranty*: A single consultant designs, constructs, and warrants specified highway components over a prescribed time period.
 - *Design-Build-Maintain*: A single consultant designs, builds, and maintains the project works for a specified period of time under a single contract.
 - *Design-Build-Operate*: A single consultant designs, builds, and operates the project (e.g., a toll road) for a specified period of time under a single contract.
 - *Design-Build-Operate-Maintain*: A single consultant designs, builds, operates, and maintains the project under a single contract.
- *Design-Bid-Build*: The traditional delivery system in which an agency will use in-house staff (or consultants) to prepare fully completed plans and specifications that are then incorporated into a bid package. Contractors competitively bid the project based on these completed plans and specifications. The agency evaluates the bids received, awards the contract to the lowest responsible and responsive bidder.
- *Design Sequencing*: The agency sequences design activities in a manner that will allow the start of each construction phase when the design for that particular phase is complete, instead of requiring the design for the entire project to be complete before allowing construction to begin.
- *Indefinite Delivery/Indefinite Quantity (ID/IQ)*: The agency will identify and develop specifications for task items. Contractors then competitively bid these task items based on unit prices for task items for a specific contract term.

- *Agency-Construction Manager*: A fee-based service in which the construction manager (CM) is exclusively responsible to the agency and acts as the agency's representative at every stage of the project.
- *Construction Manager at-Risk*: The agency engages a construction manager (CM) to act as the agency's consultant during the pre-construction phase and as the general contractor (GC) during construction.
- *Contract Maintenance (also known as Asset Management)*: The agency will outsource maintenance or rehabilitation tasks to contractors, either through traditional or performance-based contracting methods.

2.3.2 Procurement Practices

Procurement practices are the procedures agencies use to evaluate and select designers, contractors, and various consultants. Selection is based on several factors including price, technical qualifications, time, etc. The following are some of the alternative procurement practices that could potentially be considered for TSM&O projects (Trauner Consulting Services, Inc., 2007):

- *Cost-Plus-Time Bidding (A+B)*: Uses a cost parameter (A) and a time parameter (B) to determine a bid value.
- *Multi-Parameter Bidding (A+B+C)*: Extends the A+B bidding concept to include an additional cost parameter (C) that may include a quality or warranty parameter.
- *Lump Sum Bidding*: A contractor is provided with a set of bid documents that do not contain detailed quantity tables. The contractor develops quantity take-offs from the plans and estimates a lump sum price based on this take-off.
- *Alternate Design*: A bidding technique where contractors may propose and submit a bid on an alternate design that is equivalent to the design specified by the agency.
- *Alternate Bid*: The agency asks for alternate bids on specified designs. At some point before awarding the contract, the agency will decide which alternate provides the best value.
- *Additive Alternates*: A bidding technique where the agency will include most of the project scope in base-bid items, while also specifying additive alternates that may be selected if the base-plus-alternates price is within budget. The contract is awarded to the lowest responsive bidder that is within budget, considering the sum of the base bid and additive alternates.

- *Best-Value Procurement*: It allows agencies to consider price and other key factors (e.g., cost, time, etc.) in the evaluation and selection process to minimize impacts and enhance the long-term performance and value of construction.
- *Bid Averaging*: It is a procurement method that awards the contract to the bidder closest to the numerical average of the bids submitted, typically after the highest and lowest bids have been eliminated.

2.3.3 Contract Management Methods

Contract management methods refer to the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. The following are some of the contract management methods that could potentially be considered for TSM&O projects (Trauner Consulting Services, Inc., 2007):

- *Incentives/Disincentives (I/D) Provisions for Early Completion*: Provide incentive payments to contractors for completing work on or ahead of schedule, or impose disincentive payments for failure to meet the specified completion date.
- *Lane Rental*: Charges contractors a rental fee for occupying lanes or shoulders to perform contract work.
- *Flexible Notice to Proceed Dates*: Allows the contractor some discretion in establishing when the project's working days are going to start, within some specified criteria.
- *Warranties*: Used to guarantee the integrity of a product and the contractor's responsibility to repair or replace defects for a defined period
- *Liquidated Savings*: A process by which the agency pays the contractor a modest incentive for each calendar or working day that the contract is completed ahead of schedule.
- *Active Management Payment Mechanism (AMPM)*: Involves a contractual provision that provides contractors with an incentive to minimize travel time through the work zone or maximize the availability of open lanes.
- *No Excuse Incentives*: Uses monetary incentives to motivate contractors to complete the contract work on time.

2.3.4 TSM&O System Development Process

The following are some of the system development strategies (i.e., models) that could be adopted for TSM&O and ITS projects:

- *Waterfall Model*: A sequential design process in which progress is seen as flowing steadily downwards (like a waterfall) through the phases of conception, initiation, analysis, design, construction, testing, production/implementation and maintenance.
- *Agile Model*: Includes a set of principles in which requirements and solutions evolve. It encourages rapid and flexible response to change.
- *Incremental Build Model*: A method of software development where the product is designed, implemented and tested incrementally until the product is finished.
- *Spiral Model*: A risk-driven process model generator for software projects. Based on the unique risk patterns of a given project, the spiral model guides a team to adopt elements of one or more process models, such as incremental, waterfall, etc.

2.3.5 Funding Sources for TSM&O Projects

Funding for TSM&O projects could potentially come from several different avenues, including (Bond et al., 2013):

- Congestion Mitigation and Air Quality Improvement (CMAQ) Program
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- National Highway Performance Program (NHPP)
- Transportation Investment Generating Economic Recovery (TIGER)
- Highway User Revenue Fund
- Local taxes
- Unified Planning Work Program (UPWP)
- Public-private partnership

2.4 Benefit-Cost Analysis

In the Florida TSM&O Strategic Plan (FDOT, 2013c), developing a benefit-cost process and adopting it for all projects is identified as one of the activities needed to achieve the objective of funding the TSM&O program. It is identified as both a near-term (2013-2015) and long-term (2016-2018) action item.

Benefit-cost (B/C) analysis is a systematic process for calculating and comparing the benefits and costs of a project to determine if it is a sound investment (justification/feasibility), and to see how it compares with alternate projects (ranking/priority assignment) (FHWA, 2012b). The benefit-cost analysis is typically conducted using either a net present value (NPV) analysis or a benefit-cost (B/C) ratio.

Net present value (NPV) is the difference between the total benefits and the total costs, converted to a present value. Note that a project with a NPV greater than zero implies that the benefits outweigh the costs, and vice versa. The B/C ratio is calculated by dividing the incremental

monetized benefits related to a project by the incremental costs of that project. Obviously, projects with B/C ratio greater than one are considered as efficient investments, while those with B/C ratio less than one are identified as inefficient investments. Table 2.4 provides the strengths and limitations of the NPV and the B/C ratio methods.

As discussed in the table, an incremental B/C analysis is conducted if there are two or more alternative projects to compare to the base scenario. Although the procedure to conduct incremental B/C analysis is mathematically equivalent to NPV, this approach may provide greater insights into the relationships between costs and benefits of the different projects.

Detailed computation steps for these three analyses (NPV, B/C ratio, and Incremental B/C ratio) are provided in Chapters 7 and 8 of the Highway Safety Manual (HSM) (American Association of State Highway and Transportation Officials [AASHTO], 2010).

Table 2.4: Strengths and Limitations of Different B/C Analysis Methods
(Source: AASHTO, 2010)

B/C Analysis Method	Strengths	Weaknesses
B/C Ratio	<ul style="list-style-type: none"> • The magnitude of the B/C ratio makes the relative desirability of a proposed project immediately evident to decision makers. • This method can be used by highway agencies in evaluations for the FHWA to justify improvements funded through the Highway Safety Improvement Program (HSIP). Projects identified as economically justified (B/C ratio > 1.0) are eligible for federal funding; however, there are instances where implementing a project with a B/C ratio < 1.0 is warranted based on the potential for crashes without the project. 	<ul style="list-style-type: none"> • Benefit-cost ratio cannot be directly used in decision making between project alternatives or to compare projects at multiple sites. An incremental benefit-cost analysis would need to be conducted for this purpose. • This method considers projects individually and does not provide guidance for identifying the most cost-effective mix of projects given a specific budget.
NPV Analysis	<ul style="list-style-type: none"> • This method evaluates the economic justification of a project. • NPV are ordered from highest to lowest value. • It ranks projects with the same rankings as produced by the incremental B/C ratio method. 	<ul style="list-style-type: none"> • The magnitude cannot be as easily interpreted as a benefit-cost ratio.

Although benefit-cost analysis has been applied to several traditional infrastructure project assessments, the same methods cannot be directly used in analyzing TSM&O projects, for several reasons, including (FHWA, 2012b):

- Existing measures of effectiveness (MOEs) may not be sensitive to the unique benefits of TSM&O strategies such as improving travel time reliability, etc.
- Specified analysis data may be inappropriate for assessment of TSM&O benefits.

- Required analysis methods, tools, or models may not be capable of capturing the full benefits of the TSM&O strategies.
- Cost estimation parameters and framework may be inadequate.

While conducting B/C analysis for TSM&O projects, attention needs to be paid to the following items (FHWA, 2012b):

- Identify the comprehensive set of MOEs that may be impacted by the range of the varying projects to be compared.
- Identify the sources of data necessary to support the estimation of impacts on the identified MOEs.
- Identify the analysis methods that will be used to estimate the incremental impacts on the identified MOEs.
- Establish the values in dollars that will be applied to the incremental change in MOEs in order to monetize the benefit.

2.5 Existing Tools for Conducting B/C Analysis

The existing methods and tools for conducting benefit-cost analyses could be divided into three broad categories: sketch-planning methods, post-processing methods, and multi-resolution or multi-scenario methods. Sketch-planning methods provide simple, quick, and low-cost estimation of TSM&O strategy benefits and costs. Tool for Operations Benefit-Cost Analysis (TOPS-BC) is one of the sketch-planning methods that is currently being considered/used in Florida. Post-processing methods directly link the B/C analysis with the travel demand, network data, and performance measure outputs from regional travel demand or simulation models. ITS Deployment Analysis System (IDAS) and Florida ITS Evaluation Tool (FITSEVAL) are the two post-processing methods currently being considered/used by FDOT. Multi-resolution/multi-scenario methods are the most complex of the methods and are typically applied during the final rounds of alternatives analysis or during the design phases when detailed information is required to prioritize and optimize the proposed strategies.

Table 2.5 briefly lists the advantages and limitations of each of these methods. The resources required to adopt these methods in terms of budget, schedule, staff expertise, and data availability are also provided. The Operations Benefits/Cost Analysis Desk Reference provides a comprehensive overview about the existing benefit-cost analysis methods applicable to the TSM&O projects (FHWA, 2012b).

The following tools that are currently being considered/used in Florida are discussed in the following subsections:

- Florida Intelligent Transportation Systems Evaluation Tool (FITSEVAL)
- ITS Deployment Analysis System (IDAS)
- Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) Model

- Tool for Operations Benefit-Cost Analysis (TOPS-BC)

Table 2.5: Methods to Conduct B/C Analysis (Source: FHWA, 2012b)

Method	Advantages	Limitations	Resources Required ¹
Sketch-Planning Methods	<ul style="list-style-type: none"> • Ease to use • Fewer data requirements • Quick setup and analysis times • Low cost • Ability to easily customize 	<ul style="list-style-type: none"> • Order of magnitude outputs • Limited MOEs • Linear (non-dynamic) assumptions of user behaviors 	Budget: Low (\$1K - \$25K) Schedule: 1-8 weeks Staff Expertise: Medium Data Availability: Low
Post-Processing Methods	<ul style="list-style-type: none"> • Assessment of traveler behaviors • Data availability • Consistency with the regional planning process • Development of a reusable process 	<ul style="list-style-type: none"> • Analysis effort • Compatibility of tools/methods 	Budget: Medium/High (\$5K - \$50K) Schedule: 2 months to 1 year Staff Expertise: Medium/High Data Availability: Medium
Multi-resolution/ Multi-scenario Methods	<ul style="list-style-type: none"> • Assessment of short-term and long-term traveler behaviors • Assessment of nonrecurring conditions • Detail of analysis • Flexibility of the analysis 	<ul style="list-style-type: none"> • Model development and analysis effort • Compatibility of tools/methods • Complexity limits on analysis scope 	Budget: High (\$50K - \$1.5M) Schedule: 3 months to 1.5 years Staff Expertise: High Data Availability: High

¹ Estimates are provided for a “typical” analysis. Actual time and budget resources would be dependent on the number of alternatives, geographic scope, and effort required to compile the appropriate input data.

2.5.1 Florida Intelligent Transportation Systems Evaluation Tool (FITSEVAL) (FDOT, 2015c)

The Florida Intelligent Transportation System Evaluation Tool (FITSEVAL) is a sketch-planning tool developed within the Florida Standard Urban Transportation Model Structure (FSUTMS)/Cube environment, allowing a flexible, user-friendly, and consistent evaluation of ITS deployment alternatives. The tool can evaluate the following types of ITS deployments:

- Ramp Metering
- Incident Management Systems
- Highway Advisory Radio (HAR)
- Dynamic Message Signs (DMS)
- Advanced Travel Information Systems
- Managed Lanes

- Signal Control
- Transit Vehicle Signal Priority
- Emergency Vehicle Signal Priority
- Monitoring and Management of Fixed Route Transit
- Transit Information Systems
- Transit Security Systems
- Transit Electronic Payment Systems
- Smart Work Zones
- Road Weather Information Systems (RWIS)

The FITSEVAL tool produces various performance measures including mobility, safety, energy, emission, and other agency-specific measures. The outputs include the benefits, costs, and benefit-cost ratio that can be used for prioritizing improvement alternatives.

2.5.2 ITS Deployment Analysis System (IDAS) (Citilabs, Inc., 2014)

IDAS provides benefit to cost comparisons of ITS improvements individually and in combinations. It can assess the impacts and costs of the following twelve different categories of ITS deployments:

- Arterial Traffic Management Systems (ArTMS)
- Freeway Traffic Management Systems (FTMS)
- Advanced Public Transit Systems (APTS)
- Incident Management Systems (IMS)
- Electronic Payment Collection
- Rail Road Grade Crossings
- Emergency Management Services
- Regional Multimodal Traveler Information Systems
- Commercial Vehicle Operations (CVO)
- Advanced Vehicle Control and Safety Systems
- Supporting Deployments
- Generic Deployments

The IDAS software includes default values for the inputs required to calculate the costs and benefits of ITS deployments. These defaults are based on the analysis of the data presented in the USDOT ITS Benefits and ITS Unit Costs Databases. The default benefit and cost parameters and databases are customized to better reflect Florida conditions.

2.5.3 Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) Model (Gopalakrishna et al., 2012)

Developed by the Center for Urban Transportation Research (CUTR) at the University of South Florida, TRIMMS 3.0 includes monetized benefits, by region of the U.S., for the following:

congestion, air and noise pollution, climate change, fuel consumption, health, and safety. The model uses Travel Demand Management (TDM) cost data and derived impact estimates from the model to generate B/C ratios for TDM strategies (Gopalakrishna et al., 2012). The model also provides program cost-effectiveness assessment to meet the FHWA's Congestion Mitigation and Air Quality (CMAQ) Improvement Program requirements for program effectiveness assessment and benchmarking (FHWA, 2012b).

2.5.4 Tool for Operations Benefit-Cost Analysis (TOPS-BC) (Sallman et al., 2013)

TOPS-BC is a sketch-planning level decision support tool developed by the FHWA Office of Operations. It is a companion to the FHWA's Operations Benefit/Cost Desk Reference (FHWA, 2012b). This spreadsheet application is intended to provide support and guidance to transportation practitioners in the application of B/C analysis for a wide range of TSM&O strategies. The application has the following four major capabilities (Sallman et al., 2013):

1. Investigate the range of expected values associated with various TSM&O strategies
2. Map different B/C methodologies to your organization's needs
3. Estimate life-cycle costs of TSM&O strategies
4. Conduct simple spreadsheet-based B/C analysis for selected TSM&O strategies

The following TSM&O strategies are covered in the TOPS-BC tool:

- Arterial Signal Coordination
- Ramp Metering
- Traffic Incident Management
- Pretrip Traveler Information
- En-route Traveler Information
- Work Zone Management
- HOT Lanes
- Speed Harmonization
- Road Weather Management
- Hard Shoulder Running

The analyst can customize TOPS-BC by replacing the default parameters with local values. Note that the default costs are obtained from the USDOT ITS Joint Program office Cost Database.

2.5.5 Summary of Existing B/C Analysis Tools

Tables 2.6 and 2.7 summarize the strategies and MOEs that could be analyzed by FITSEVAL, IDAS, TOPS-BC, and TRIMMS, respectively. As can be observed from the tables, IDAS and TOPS-BC have the capabilities to analyze all the commonly adopted strategies and the commonly used MOEs.

Table 2.6: Available Tools/Methods Mapped to Strategies Analyzed (FHWA, 2012b)

Tool/ Methodology	Travel Demand Mgmt.	Public Transit Systems	Arterial Traffic Mgmt.	CVO	HOT Lanes	Freeway Mgmt. Systems	Incident Mgmt. Systems	Regional Multimoda l Traveler Info	Work Zone Mgmt.
FITSEVAL			•			•	•	•	
IDAS	•	o	•	•	•	•	•	•	•
TOPS-BC	o	o	•	o	•	•	•	•	•
TRIMMS	•	•							

• Addresses most elements of strategy; o addresses some elements of strategy.

Table 2.7: Available Tools/Methods Mapped to MOEs Analyzed (FHWA, 2012b)

Tool/ Methodology	Mobility (Travel Time Savings)	Reliability (Total Delay)	Safety (Number and Severity of Crashes)	Environment (Emissions Reduction)	Energy (Fuel Use)	Productivity (Public Agency Costs/ Efficiency)	Vehicle Operating Cost Savings
FITSEVAL	•		•	•	•		•
IDAS	•	•	•	•	•	•	•
TOPS-BC	•	•	•	o	•	•	•
TRIMMS	•			•	•		

• Primary analysis capability; o secondary analysis capability.

2.6 Benefits of TSM&O Strategies

Improved technologies over the last decade have not only allowed for better transportation operations, but also have increased the importance of M&O in the project development process. Express lanes and ramp metering are two TSM&O strategies being used in corridor management efforts along I-95 in South Florida.

A case study conducted in Cincinnati, Ohio to compare the benefits and costs of operational measures versus traditional capacity improvements highlights the investment efficiency of using TSM&O strategies (FHWA, 2012b). Table 2.8 lists the results from the evaluation of expanding the regional traffic management and traveler information program, ARTIMIS, compared to a single-lane widening project (FHWA, 2012b). Enhancements from the operational strategies resulted in a B/C ratio of 12:1, a marked return on TSM&O investment compared to the added capacity method.

Incorporating TSM&O consideration during the planning phase of a project can result in greater benefits from infrastructure investments (FHWA, 2013). Reducing congestion and improving travel time promotes increased safety for road users, emergency responders, and maintenance

staff (FHWA, 2013). Although benefits may be realized later through future operational initiatives, some TSM&O strategies can provide corridor improvements much sooner, such as bus lanes, express lanes, and raised medians. Other important advantages include less interruptions for road users in work zones and reduced costs for future operational and ITS applications (FHWA, 2013). Moreover, the installation of fiber optic cable infrastructure during the construction phase may reduce the cost of a future operational deployment.

Table 2.8: ARTIMIS Operational Project versus a Traditional Roadway Widening Project
(Source: FHWA, 2012b)

Selected Measure	ARTIMIS	Added Lane Project
Miles of improvements	88	10
Fatality accidents	-3.2%	+0.3%
Mobility (time savings)	500 hours	800 hours
Travel time reliability saving	6,900 hours	5,800 hours
Emissions	-3.6% to -4.5%	+0.3% to +1.4%
Estimated annual benefit	\$53 Million	\$ 35 Million
Total project cost	\$ 40 Million	\$ 800 Million
B/C ratio	12:1	1.1:1

Addressing congestion through operations can also reduce the magnitude of construction associated with adding additional lanes and help to alleviate motorist frustration, especially along the interstate system. More importantly, TSM&O measures allow for the optimization of existing roadway performance, thus “taking back” the capacity lost to congestion (FHWA, 2013).

2.7 Challenges in Implementing TSM&O Strategies

The inclusion of future M&O elements early in the project development process may present challenges. For example, if general contractors lack the experience or expertise to install field components during the construction phase of a roadway project, replacement measures could prove costly at a future date, essentially negating the cost saving of including operations components in the design phase.

TSM&O components included in a roadway improvement project for future operations, such as ITS and emergency responder facilities, may be considered unnecessary and eliminated from consideration due to limited funding. However, the cost of implementing these measures at a later date, may prove more expensive (FHWA, 2013). Additionally, Operations efforts requiring monitoring by skilled staff, are often dismissed during the budgeting process.

A primary challenge comes with shifting the culture within the transportation community to include TSM&O in all levels of the project development process, especially since benefits may not be immediately realized. Without policy change, viewing roadway projects through an operational lens may also present difficulties for transportation staff, decision makers, and other stakeholders.

2.8 Chapter Summary and Conclusions

As congestion and safety concerns increase throughout the nation, alternative solutions provided by TSM&O strategies are gaining in acceptance. Nevertheless, few state agencies, such as DelDOT and ALDOT have prioritized TSM&O in the early phases of the project development process. While some State DOTs, such as Pennsylvania and Missouri DOT have integrated operational considerations, to some degree, into design and policy guidelines for transportation practitioners, progress in mainstreaming TSM&O throughout the project development process is slow in taking shape.

As with other states, the greater part of TSM&O efforts in Florida come in the form of ad hoc projects for existing infrastructure and primarily involve ITS technologies. However, the degree of TSM&O inclusion in the planning process is uncertain. Cooperative efforts between FDOT planning and operations divisions vary among districts. Moreover, the consideration of potential TSM&O strategies as viable alternatives to traditional expansion at the decision-making level is also unclear. Additionally, TSM&O champions are not typically included in the ETDM review process as the current state-of-the-practice.

Incorporating TSM&O related objectives, strategies, and performance measures into the traditional transportation infrastructure projects would be a sensible approach to help the FDOT optimize project expenditures. Furthermore, TSM&O strategies need to be “mainstreamed” into the transportation planning and programming processes in all functional areas across FDOT at all levels. This approach would help shift the focus from individual project-based approach to objectives-driven and performance-based approach.

All prospective roadway projects are potential candidates for alternative capacity solutions involving TSM&O strategies. The future of congestion and safety management must incorporate the most cost-effective measures to keep up with the growing number of road users depending on safe and reliable travel. To optimize roadway improvements to support M&O strategies, TSM&O considerations must occur early in the project development process.

3 – FDOT GUIDELINES

To explore the extent to which TSM&O/ITS is represented in current FDOT project development publications, guidelines listed in Table 2.2, Chapter 2, were reviewed for potential inclusion of TSM&O, Transportation Systems Management (TSM), Intelligent Transportation Systems (ITS), and traffic operations. Documents reviewed included:

- CADD Manual
- Design Standards
- Efficient Transportation Decision Making (ETDM) Manual
- Florida’s ITS Integration Guidebook
- Florida Greenbook
- Intersection Design Guide (IDG)*
- Plans Preparation Manual (PPM)*
- Practical Design Handbook
- Project Development and Environment (PD&E) Manual
- Project Management Handbook
- Traffic Engineering Manual (TEM)
- Work Program Instructions

Existing guidelines were initially reviewed in July, 2016 in conjunction with research efforts to explore the state-of-the-practice of TSM&O at the FDOT to determine what was needed to facilitate the mainstreaming of TSM&O throughout the project development process. These findings are reported in Section 3.1, Initial Review Results.

Over the course of this research effort, FDOT made significant updates to these existing project development publications to include language relating to TSM&O/ITS. Therefore, a subsequent review of the updated documents was conducted. Findings from this review are reported in Section 3.2, Current FDOT Guidelines.

3.1 Initial Review Results

The following sections briefly describe the function of each FDOT publication and language pertaining to TSM&O, TSM, or ITS found in each document during the initial review process.

3.1.1 CADD Manual

The FDOT CADD Manual contains the FDOT’s criteria for computer generated project plans and organization. The FDOT also has developed CADD software that incorporates this criteria to maintain standards and promote quality assurance (FDOT, 2016a). The manual does include

CADD production standards and procedures for ITS plans throughout the document; however, no language specific to TSM&O is included or referenced in the manual.

3.1.2 Design Standards

The FDOT Design Standards publication provides required standards for the design of roadways, bridges, and other structures for SHS facilities. ITS design elements pertaining to CCTV poles and placement is covered in Index series 18000 (FDOT, 2016b); however, no specific language referring to TSM&O is mentioned in the document.

3.1.3 Efficient Transportation Decision Making Manual

The purpose of the Efficient Transportation Decision Making (ETDM) process is to allow agencies and other stakeholders to engage early in the transportation planning process to provide input on environmental concerns and potential issues that may affect the scope of a project (Ch. 2, Sec. 2.1) (FDOT, 2015a). The ETDM manual provides information to consider as qualifying transportation projects are reviewed during the ETDM planning and programming screens of the Environmental Screening Tool (EST).

An Environmental Technical Advisory Team (ETAT) is assigned to each FDOT District to facilitate the process and provide comments to FDOT through the EST, described in the ETDM manual, Ch. 2, Sec. 2.1. Comments provided assist the FDOT in developing the project scope for a PD&E study as noted in the PD&E Manual, Part 1, Ch. 2, Sec. 2.1 (FDOT, 2015b).

A key objective of the ETDM process is the linking of planning and programming phases with the PD&E phase of transportation projects (FDOT, 2015a). Projects included or prioritized in the LRTP are considered during the Planning Screen of the ETDM process. Identified projects then enter the Programming Screen for the development of the Five-year Work Program (FDOT, 2015a).

The ETDM Manual (Ch. 1, Sec. 1.1) provides information to be considered during the ETDM Planning and Programming Screens to review qualifying transportation projects. Qualifying roadway projects include expansion (widening) projects, new facilities, reconstruction or realignments, new interchanges or modifications, and new bridge structures (Ch. 2, Sec. 2.3.1) (FDOT, 2015a).

Although the primary objective of the ETDM Manual is to provide guidance to transportation professionals while navigating the EST process screens, currently no language specific to TSM&O is included or referenced in the manual (FDOT, 2015a).

3.1.4 Florida Intersection Design Guide (FIDG)

The Florida Intersection Design Guide (FIDG) provides guidelines for at-grade intersection design (FDOT, 2015d). Although coordinated traffic signals and interconnected systems are

discussed, ITS is mentioned only briefly, and no language specific to TSM&O is included or referenced in the document.

3.1.5 Florida's ITS Integration Guidebook

The ITS Integration Guidebook focuses on the institutional and technical ITS integration processes, and implementation of integration processes as part of an ITS strategic plan (FDOT, 2002). For successful integration, the guidebook recommends ITS be incorporated in the planning phase of the project development process to achieve effective systems that maximize the benefits of technology and information (FDOT, 2002). Although ITS is essentially a TSM&O component, reflective of the publication date, specific language referring to TSM&O is not included in the document.

3.1.6 Florida Greenbook

The Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways, also known as the Florida Greenbook, is a comprehensive reference containing minimum standards and criteria for the design, construction, and maintenance of all public bridges and roadways, and infrastructure elements (FDOT, 2013b). This manual is intended for use in the design phase, or later, in the project development process for non-state-maintained roadways.

TSM is briefly described, however, it is primarily used in relation to public transit needs and coordination among agencies (Ch. 13, Sec. A) (FDOT, 2013b). References pertaining to TSM&O or ITS are not mentioned in the manual.

3.1.7 Plans Preparation Manual (PPM)

The Plans Preparation Manual (PPM) targets the design phase of the project development process, and consists of two volumes: (1) Design Criteria and Process, and (2) Plans Preparation and Assembly (FDOT, 2016c). Although language pertaining to TSM&O specifically was not found in either PPM volume, Volume 1 references heavily the PD&E Manual.

Design guidelines related to ITS components are covered extensively in Volume 1 of the PPM, and briefly explains the use of ITS devices for roadway improvements while mentioning the integration of transportation systems (Vol. 1, Ch. 7, Sec. 7.5.1) (FDOT, 2016c). The preparation requirements for ITS plans are located in Volume 2 of the PPM (Vol. 2, Ch. 29) (FDOT, 2016c).

3.1.8 Practical Design Handbook

The Practical Design Handbook was published in 2014 as a guide to promote efficient design practices by focusing on a practical approach to design, rather than traditional, that will provide the highest return on investment (FDOT, 2014a). In the practical design approach, design is

based on safety and operational performance. No language specific to TSM&O is included or referenced in the document.

3.1.9 Project Development & Environment (PD&E) Manual

The Project Development and Environment (PD&E) Manual serves as the primary guideline for developing projects while adhering to all State and Federal laws and requirements (FDOT, 2015b). The manual constitutes two parts: Part 1 concentrates on the procedural aspects of the project development process, and Part 2 provides detailed information needed for completing the PD&E process.

TSM&O language is present in several chapters of Part 1 of the PD&E Manual. The first statement, located in Chapter 4, requires a TSM&O alternative to be evaluated in addition to no-action and build alternatives (Part 1, Ch. 4, Sec. 4.2.4). The Preliminary Engineering Report (PER) also requires a discussion of the alternatives analysis, including the TSM&O alternative (Part 1, Ch. 4, Sec. 4.2.9.1) (FDOT, 2015b).

A Transportation Systems Management (TSM) evaluation statement is included in the Record of Decision (ROD) sample document, from the FHWA Division Office, following the completion of the Final Environmental Impact Statement (FEIS) process (Part 1, Ch. 9, Figure 9.6). However, discussion of TSM does not appear anywhere else in Chapter 9 (FDOT, 2015b).

Also mentioned briefly in Chapter 10, TSM alternatives shall be evaluated, where appropriate (Part 1, Ch. 10, Sec. 10-3.2) on non-federal projects during the environmental evaluation process. This applies to non-federal projects that require ETDM screening followed by a State Environmental Impact Report (SEIR) processed exclusively by the District (Part 1, Ch. 10, Sec. 10-3.2) (FDOT, 2015b).

In Part 2 of the PD&E Manual, TSM&O language is present only in the Chapter 6 information relating to the evaluation of alternatives during the PD&E process. Nonetheless, a brief description of TSM&O, including examples of TSM&O strategies, is provided (Part 2, Ch. 6, Sec. 6-2.2.2). Strong language is also included, requiring that TSM&O strategies must be reviewed, and found not to meet the purpose and need, before added-capacity alternatives can be considered (Part 2, Ch. 6, Sec. 6-2.2.2) (FDOT, 2015b).

3.1.10 Project Management Handbook

The FDOT Project Management Handbook consists of two parts and covers common issues that arise in project management (Part 1), as well as phase-specific (i.e., planning, PD&E, design, etc.) project management (Part 2) (FDOT, 2016d). TSM is discussed as one of six types of corridor studies conducted in planning projects (Part 2, Ch. 1), and briefly mentioned in Chapter 2 in the Development of Alternatives section (Part 2, Ch. 2) (FDOT, 2016d). Both locations reference information found in the PD&E Manual.

The handbook also mentions ITS, although briefly, in relation to Federal requirements for state agencies and MPOs. Required by FHWA, ITS elements must be included in the LRTP, and each MPO area must have a regional ITS architecture in compliance with Federal architecture standards (Part 1, Ch. 8) (FDOT, 2016d).

Although TSM&O is not mentioned specifically in the handbook, the 2060 Florida Transportation Plan (FTP) includes several long-term goals for optimizing and increasing transportation system efficiency and travel reliability (Part 1, Ch. 8). Strategies to implement the 2060 FTP goals are included in the FDOT's Annual Performance Report, and focus on performance-based measures (Part 2, Ch. 1) (FDOT, 2016d).

3.1.11 Traffic Engineering Manual (TEM)

The Traffic Engineering Manual (TEM) provides standards and guidelines for District Traffic Operations engineers and staff for traffic elements on State Highway System (SHS) facilities (FDOT, 2012). No language specific to TSM&O is included or referenced, and topics related to ITS, also are not covered in the manual.

3.1.12 Work Program Instructions

The Work Program Instructions document is published annually by the Work Program Development and Operations Office to assist FDOT staff with the development of the FDOT Five-year work program, maintaining compliance with State law (FDOT, 2015e). The instructions reflect federal, state, and FDOT funding and policy directives.

Although the document does not contain specific TSM&O language, programming guidelines are provided for projects involving ITS technologies included in the Ten Year ITS Cost Feasible Plan for the statewide Strategic Intermodal System (SIS) (Part III, Ch. 17, Sec. A.2). Programming instructions are also included for stand-alone ITS projects, including traffic signal systems for arterial traffic management (Part III, Ch. 17, Sec. B.1).

In addition to instructions related to the ITS program, programming guidelines are also provided for the traffic engineering and operations program (Part III, Ch. 38). This program targets traffic operations problems, and includes all aspects of the project development process that involve traffic operations, engineering, and ITS (Part III, Ch. 38). Programming instructions for transit projects are also provided, encompassing a number of transit programs (Part III, Ch. 15, Sec. H).

3.2 Current FDOT Guidelines

The following sections discuss the current FDOT guidelines in comparison to the earlier versions researched in the initial review of documents. The location of TSM&O language found in each publication is summarized in Section 3.1.

3.2.1 CADD Manual

The current version of the FDOT CADD Manual (2017) is organized differently than the previous version. Although the CADD production standards and procedures for ITS plans generally remained the same, the ITS section is now located after signalization standards and before lighting standards (FDOT, 2017b). However, language specific to TSM&O is not included or referenced in the current manual.

3.2.2 Design Standards

The ITS design elements included in current FDOT Design Standards for fiscal year 2017-2018 (FDOT 2017c) remained unchanged from the previous 2016 version. No specific language referring to TSM&O is mentioned in the document.

3.2.3 Efficient Transportation Decision Making (ETDM) Manual

As with the previous version (FDOT, 2015a), the current version of the Efficient Transportation Decision Making (ETDM) manual, revised in 2017, also contains no reference to TSM&O (FDOT, 2017d).

3.2.4 Florida Intersection Design Guide (FIDG)

The Florida Intersection Design Guide (FIDG) was removed from publication on December 31, 2017, and all information contained in the document was incorporated into a new publication, the FDOT Design Manual (FDM), released in January, 2018 (FDOT, 2017e).

3.2.5 Florida's ITS Integration Guidebook

The ITS Integration Guidebook discussed in Chapter 3, Sec. 3.1.5 is a stand-alone document and remains the current version (FDOT, 2002).

3.2.6 Florida Greenbook

As with the 2013 version of the Florida Greenbook (the Manual of Uniform Minimum Standards for Design, Construction and Maintenance for Streets and Highways), the current version (2016) briefly describes TSM in relation to public transit needs and coordination among agencies (Ch. 13, Sec. A) (FDOT, 2016e). However, the current document also briefly mentions ITS in the work zone safety chapter (Ch. 11, Sec. E.1.c) (FDOT, 2016e). Other than these locations, references pertaining to TSM&O or ITS are not mentioned in the manual.

3.2.7 Plans Preparation Manual

Following the initial review of the Plans Preparation Manual (PPM), (FDOT, 2016c), FDOT released an updated version in 2017. However, future updates to PPM information will be

incorporated in the FDM, released in January, 2018, and the PPM will no longer act as a stand-alone document.

3.2.8 Practical Design Handbook

Publication of the Practical Design Handbook has been discontinued by FDOT.

3.2.9 Project Development & Environment (PD&E) Manual

Over the last several years, FDOT has made significant revisions to the PD&E Manual compared to the 2015 version initially reviewed during this research effort. The current 2017 version has been reorganized, and now includes a number of references to TSM&O and ITS in Part 2 of the manual. TSM&O is covered in Chapter 3, while ITS is covered in Chapters 2 and 3 of Part 2 (FDOT, 2017f).

As with the 2015 manual, the current manual requires a TSM&O alternative is to be evaluated in addition to no-action, build, and multimodal alternatives (Part 2, Ch. 3, Sec. 3.2.4). A brief description of TSM&O and example alternatives are also provided (Part 2, Ch. 3, Sec. 3.2.4.2). The TSM&O alternative, whether or not it meets the purpose and need for the project, must be discussed in the Preliminary Engineering Report (PER) and Environmental Document (Part 2, Ch. 3, Sec. 3.2.4.2), as well as the Engineering Analysis Technical Memorandum (Part 2, Ch. 3, Sec. 3.2.4.4.2).

Although not specifically required, hybrid alternatives that utilize TSM&O strategies in the Build alternative may be considered during the planning phase by the project manager and project team (Part 2, Ch. 3, Sec. 3.2.4.4). If considered, the project manager is required to seek input from the District TSM&O Program Engineer early in the alternative's development process (Part 2, Ch. 3, Sec. 3.2.4.4).

The evaluation of an Express Lanes alternative for PD&E projects is required for SHS limited access facilities where previous capacity improvements have not been able to meet travel demand (Part 2, Ch. 3, Sec. 3.2.5.4). The Express Lanes alternative is to include dynamic tolling.

Alternatives for projects funded by federal funds that involve ITS technologies, including Express Lanes and other TSM&O alternatives, must be based on systems engineering analysis and comply with regional ITS architecture (Part 2, Ch. 3, Sec. 3.2.5.8). A high-level ConOps and a Preliminary System Engineering Management Plan (PSEMP), documenting the project's system engineering process, is also required (Part 2, Ch. 3, Sec. 3.2.5.8). Additionally, coordination with the District TSM&O Engineer or program manager and the County Engineer is required when developing the PSEMP (Part 2, Ch. 3, Sec. 3.2.5.8).

ITS is mentioned briefly in the Traffic Analysis (Part 2, Ch. 2, Sec. 2.2.2.1), and Project Coordination guidelines (Part 2, Ch. 3, Sec. 3.2.2). A review of existing ITS documents is required for projects that involve existing ITS (Part 2, Ch. 3, Sec. 3.2.3.4.4).

The only reference to TSM&O in Part 1 of the current PD&E manual occurs in the Record of Decision (ROD) sample document, from the FHWA Division Office, following the completion of the Final Environmental Impact Statement (FEIS) process (Part 1, Ch. 9, Figure 9.11). The evaluation statement now refers to the “Transportation Systems Management and Operations (TSM&O)” alternative rather than a “TSM” alternative stated in the previous 2015 version.

3.2.10 Project Management Handbook

No updates have occurred in the Project Management Handbook since initially reviewed in 2016 (see Section 3.1.10 of this report).

3.2.11 Traffic Engineering Manual (TEM)

No language specific to TSM&O is included or referenced in the current version (2017) of the TEM, and topics related to ITS, also are not covered in the manual (FDOT, 2017g).

3.2.12 Work Program Instructions

ITS inclusion in the current version of the Work Program Instructions remains the same as the 2015 version initially reviewed (see Section 3.1.12 of this report).

3.3 Summary of Current FDOT Guidelines

Current FDOT procedural and design guidelines were reviewed to determine the extent to which TSM&O or TSM language was present. The inclusion of ITS language was also explored. Table 3.1 summarizes the location where language was present relating specifically to TSM&O or TSM. Recommendations for guidelines, discussed in Chapter 11 of this report, were based in part on the results of this review process.

Table 3.1: Summary of TSM&O Language in Current FDOT Publications

FDOT Publication	TSM&O Language	Subject
CADD Manual	None	
Design Standards	None	
Efficient Transportation Decision Making (ETDM) Manual	None	
Florida Intersection Design Guide (FIDG)*	Incorporated into the Florida Design Manual (FDM) released in 2018	

Table 3.1: Summary of TSM&O Language in Current FDOT Publications (continued)

FDOT Publication	TSM&O Language	Subject
Florida's ITS Integration Guidebook	None	
Florida Greenbook	Ch. 13, Sec. A	Public Transit
	Ch. 11, Sec. E.1.c	Nature of the work zone
Plans Preparation Manual (PPM)*	Incorporated into the Florida Design Manual (FDM) released in 2018	
Practical Design Handbook	Publication discontinued	
Project Development and Environment (PD&E) Manual	Part 2, Ch. 3, Sec. 3.2.4	Alternatives Analysis
	Part 2, Ch. 3, Sec. 3.2.4.2	TSM&O alternative included in the Preliminary Engineering Report (PER)
	Part 2, Ch. 3, Sec. 3.2.4.4	Build Alternatives; TSM&O/Build hybrid project
	Part 2, Ch. 3, Sec. 3.2.4.4.2	TSM&O alternative discussion in the PER and Engineering Analysis Technical Memorandum
	Part 2, Ch. 3, Sec. 3.2.5.4	Express Lanes
	Part 2, Ch. 3, Sec. 3.2.5.8	Preliminary System Engineering Management Plan (PSEMP) for ITS and TSM&O alternatives
	Part 2, Ch. 3, Sec. 3.2.10.2	Preliminary Engineering Report (PER)
	Part 1, Ch. 9, Figure 9.11	Final EIS, Sample Record of Decision (ROD)
Project Management Handbook	Part 2, Ch. 1	Corridor Studies
	Part 2, Ch. 2	Development of Alternatives
Traffic Engineering Manual (TEM)	None	
Work Program Instructions	None	

4 – DISTRICT SURVEY I

A two-part online survey questionnaire consisting of a variety of questions related to TSM&O was administered to project managers in the TSM&O, ITS), and Traffic Operations groups in each of the seven FDOT Districts, including the Florida Turnpike Enterprise (FTE), in July 2016. Information requested in the survey is provided in Appendix A.

Part I of the questionnaire explored both general and specific information related to TSM&O practices in the project development process. Questions ranging from the general understanding of the location and group of TSM&O staff, TSM&O involvement in project phases, and challenges with TSM&O implementation were asked. Coordination practices between TSM&O staff and planning, design, and construction staff, was also requested.

Part II of the questionnaire focused on the project delivery systems, procurement practices, contract management methods, and system development strategies (i.e., models) that are currently being used by the seven FDOT Districts and FTE for their TSM&O and ITS projects. Additionally, the survey questionnaire also requested information on the existing funding sources for TSM&O and ITS projects.

4.1 Part I Survey Results

Participants that responded to the survey included at least one project manager from six of the seven FDOT Districts and the FTE. However, four project managers from District Four (D4) responded, resulting in a total of 11 responses overall. Position titles and work groups varied among these participants. All responses for Part I of the survey questionnaire are provided in Tables B.1 through B.7 in Appendix B. Missing responses to questions are marked as *No Answer*.

4.1.1 TSM&O in the Project Development Process

Survey participants were asked to select each project development process phase when TSM&O is generally considered in their District. Phase options included Planning, Design, Construction, Operations, None, and Not sure. Ten participants replied to this question. Results, listed in Table B.1, Appendix B, and illustrated in Figure 4.1, reveal that the level of TSM&O inclusion varies somewhat throughout the State; however, TSM&O strategies are more often considered during project design and operations phases (80% each) in the majority of Districts, and the FTE.

Districts Six (D6) and Seven (D7) indicated that TSM&O is included in all phases of the project development process, while District Three (D3) responded that TSM&O is generally considered only during the operations phase. District One (D1) considers TSM&O in all phases except planning, and District Five (D5) includes TSM&O only during planning and design. District Two (D2) and the FTE consider TSM&O strategies during all phases except construction.

Responses for D4, with four respondents, were mixed and included TSM&O consideration in all phases (1 of 4 respondents – a TSM&O Project Engineer), the design phase only (1 of 4 respondents), and the operations phase only (1 of 4 respondents). Overall, more than half (60%) of the participating project managers indicated that TSM&O strategies are considered during the planning phase of the project development process.

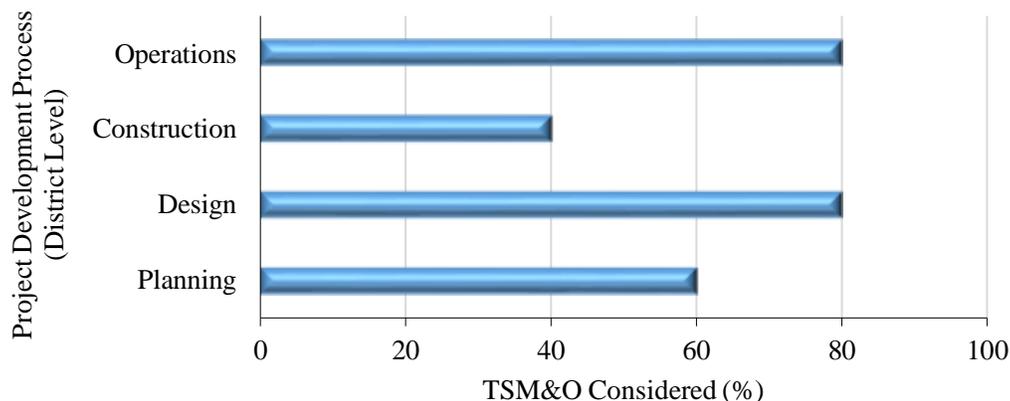


Figure 4.1: District Level TSM&O Consideration in the Project Development Process

4.1.2 Office and Work Group of TSM&O Staff

To explore perceptions relating to TSM&O leadership in the FDOT, survey participants were asked to select which office(s) they consider TSM&O staff to be located from the following options: Central Office, District Office, or Not sure. All 11 responding project managers, representing each of the seven FDOT districts and the FTE, replied to this question. Illustrated in Figure 4.2, results indicate that nearly 73% (8 of 11) of project managers consider TSM&O staff to be located in both the Central and District offices. Fewer respondents, 9% (1 of 11), selected the District office only, while 18% (2 of 11) selected the Central Office only.

Selections were mixed in D4, with four participating project managers, and included both the Central and District offices (1 of 4 respondents), the District office only (1 of 4), and the Central office only (2 of 4). Overall, these results indicate that project managers related to TSM&O/ITS activities generally perceive TSM&O leadership to be present at both the State and District levels in Florida. Survey responses to this question are shown in Table B.2, Appendix B.

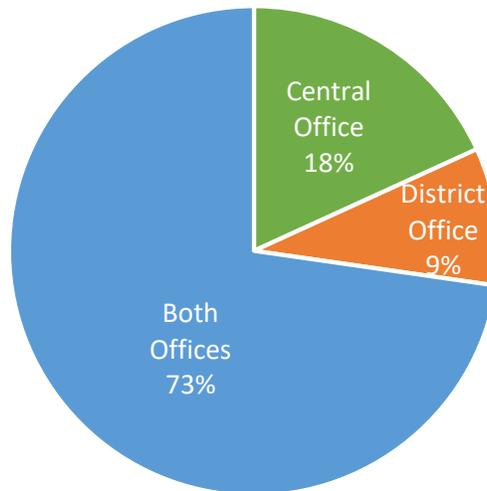


Figure 4.2: Perceived Location of TSM&O Staff

Survey participants were also asked to select which group(s) that they consider TSM&O staff to work in, from options listed in Table 4.1. Of the 11 responding project managers, 23 responses were collected. All 11 project managers replied that TSM&O staff should work in the ITS group (within Traffic Operations), resulting in the greatest percentage of responses (48%, or 11 of 23 responses). Eight of the eleven project managers (35% of responses) also selected the Traffic Operations group.

Selections among the four participating project managers in D4 varied with two (2 of 4) respondents selecting both work groups, Traffic Operations and ITS (within Traffic Operations), and two (2 of 4) selecting the ITS group (within Traffic Operations) only. Project managers from three of the seven districts, D5, D6, and D7, as well as the FTE, also consider TSM&O staff to work in the planning group, resulting in 17% (4 of 23) of responses. With the exception of D6, these districts (including FTE) selected all three work groups. Additional groups were also mentioned by participants from D5 and D7 as listed in Table 4.1.

Table 4.1: Perceived Work Group of TSM&O Staff

Response	Number	%
Traffic Operations group	8	35
ITS group (within Traffic Operations)	11	48
Planning group	4	17
Not sure	0	0
Total	23	100

Additional remarks: Executive Management (D5), Production Department and Construction Department (D7)

Overall, approximately 46%, or 5 of the 11 survey participants, consider TSM&O staff to work in both the Traffic Operations group and the ITS group (within Traffic Operations), while three participants (27%, 3 of 11) consider all three work groups. Just one survey participant (9%, 1 of 11) considers TSM&O staff to work in both the planning and ITS groups, while two of the eleven participants (18%) consider TSM&O staff to work only in the ITS group (within Traffic Operations). Survey responses to this question are shown in Table B.2, Appendix B.

4.1.3 TSM&O Staff in the Project Development Process

A series of questions were asked relating to the interaction of TSM&O staff with other staff members involved in various phases of project development. In addition, the involvement of TSM&O staff and traffic operations engineers in the project development process was also explored. The following sections discuss the findings from this series of questions. Complete responses are listed in Tables B.3, B.4, and B.5 in Appendix B.

4.1.3.1 Interaction with Planning Staff

Survey participants were asked if planning staff engage TSM&O staff in their District, and if so, to briefly explain the process. Eight project managers, one from each District and the FTE, replied to this question. Of the eight responses, seven (88%) stated that planning staff do engage TSM&O staff, and one project manager, D1, indicated that planning staff do not coordinate with TSM&O staff. However, the process by which planning staff engage TSM&O staff varies among the Districts.

Project managers from D3 and D6 mentioned that an official process has yet to be established, while other Districts stated that the level of engagement of planning staff is inconsistent (D4) or primarily limited to larger projects (D2), the review of long-range plans (D4), or initial scope development efforts (D7). Alternatively, planning and TSM&O staff in D5 meet briefly on a weekly basis, while the Turnpike TSM&O Task Team within the FTE meet regularly to discuss TSM&O strategies and initiatives. Survey responses to this question are shown in Table B.3, Appendix B.

To determine the level of interaction between staff members, project managers were asked to select the degree to which planning staff work with TSM&O staff from the following options: Not at all, Very little, Somewhat, or Always. All 11 survey participants, representing each of the seven FDOT districts and the FTE, responded to this question. Results, shown in Figure 4.3, reveal that over half (55%), or six of the eleven respondents, claimed that planning staff work with TSM&O staff very little of the time, and 27% (3 of 11 project managers) indicated that planning staff work somewhat closely with TSM&O staff in their respective Districts. In contrast, 18%, or two Districts (D5 and FTE) stated that a consistent level of interaction exists between planning and TSM&O staff.

Interestingly, of the project managers that claimed a greater level of interaction between planning and TSM&O staff, the majority also hold positions with “TSM&O” in the title. One example is

in D4, with four survey participants, where the District TSM&O Engineer experienced a greater level of interaction with planning staff compared to other project managers with different position titles. Survey responses to these questions are shown in Table B.3, Appendix B.

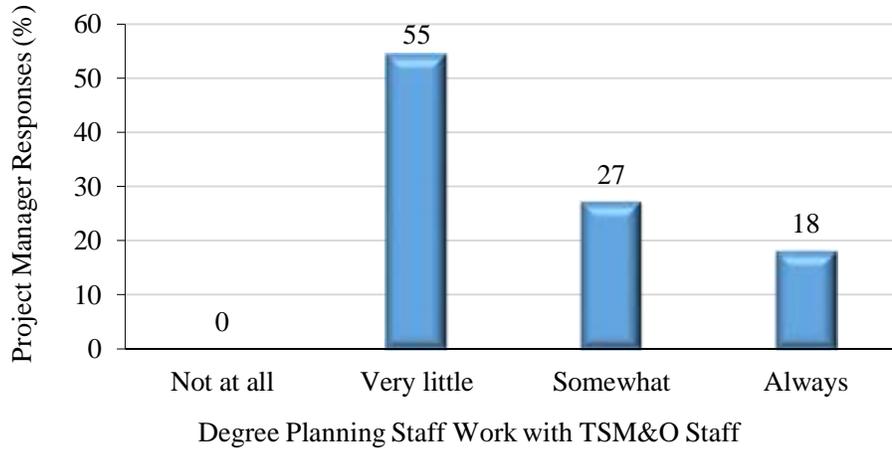


Figure 4.3: Interaction between Planning and TSM&O Staff

4.1.3.2 Interaction with PD&E Staff

Similar results were found when survey respondents replied to questions related to the interaction between Project Development and Environment (PD&E) staff and TSM&O staff during the PD&E process. Of the 11 responses received, nearly 64% (7 of 11) of project managers indicated that PD&E staff do engage TSM&O staff in their District. However, three project managers (27%) were not sure (D3, D4, and FTE), and one project manager (9%) from D1 stated that PD&E staff currently do not seek to coordinate with TSM&O staff during the PD&E process.

The process and level of interaction between PD&E and TSM&O staff also varies per District. Minimal engagement by PD&E staff, primarily limited to initial kick-off and scope development meetings, was reported by project managers from D4 and D7. Other Districts (D4, D5, and D6) report that PD&E staff are involved in various review efforts. The involvement of PD&E staff with Express Lane projects (D2 and D6), as well as System Engineering (SE) aspects such as Concept of Operations (ConOps) (D5 and D6), were also mentioned.

As shown in Figure 4.4, of the 11 responding project managers, nearly 55% (6 of 11) stated that PD&E staff work very little with TSM&O staff, while 45% (5 of 11) reported a somewhat closer level of interaction. Similar to interactions with planning staff, the majority of project managers that stated greater interaction with PD&E staff also hold TSM&O titled positions. Survey responses to these questions are shown in Table B.3, Appendix B.

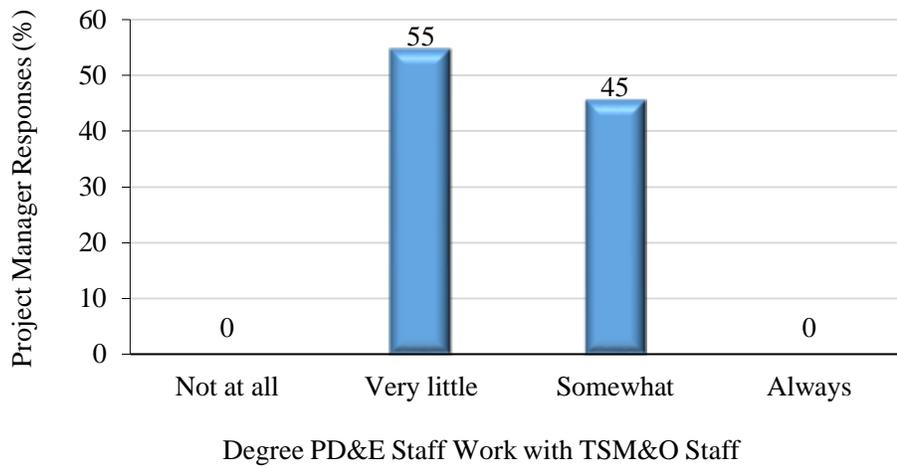


Figure 4.4: Interaction between PD&E and TSM&O Staff

4.1.3.3 Interaction with Design Staff

Eleven project managers replied to similar questions on the interaction between design staff and the process by which design staff engage TSM&O staff. Response results reveal that nine of the eleven project managers (nearly 82%) claim that design staff do engage TSM&O staff in their District. Just over 18%, or two project managers, one each from D3 and D4, responded as not sure.

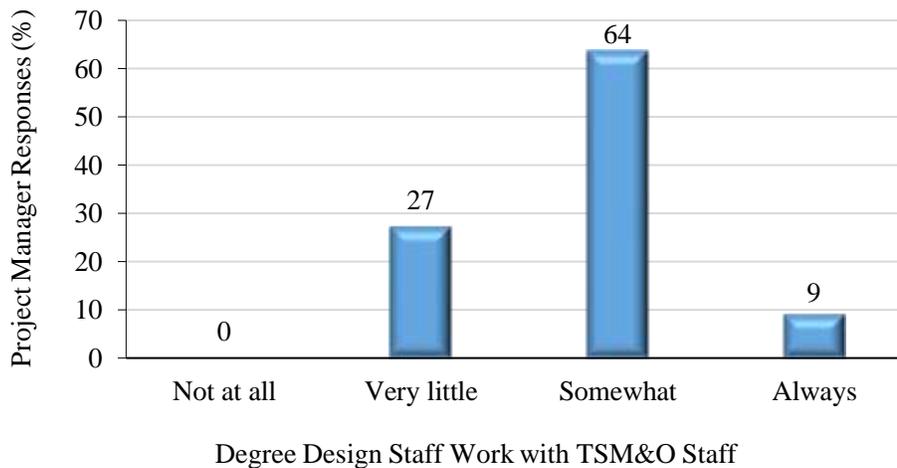


Figure 4.5: Interaction with Design Staff

The process of engagement by design staff ranges from informal or as needed (D2, D4, and D5), to scope development (D1, D5, and D7) and review processes (D1, D4, and D5). Several project

managers relayed a greater level of engagement for Express Lane projects (D6) and discussions on TSM&O alternatives for current and future Work Program projects (FTE).

When questioned about the degree that design staff work with TSM&O staff, project managers responded as shown in Figure 4.5. A considerable number of survey participants, 64% (7 of 11), indicated that design staff work somewhat of the time with TSM&O staff, while 27% (3 of 11) stated interaction is very little (D3 and two participants from D4). Conversely, the D1 participant, (9%, or 1 of 11) indicated a consistent level of interaction with design staff. Survey responses to these questions are shown in Table B.4, Appendix B.

4.1.3.4 Interaction with Construction Staff

As with the previous questions, survey participants were asked to rate the level of interaction between construction staff and TSM&O staff in their respective Districts. Illustrated in Figure 4.6, responses from 11 survey participants, representing each of the seven FDOT districts and the FTE, reveal that construction staff work very little of the time (45%, or 5 of 11) with TSM&O staff in some Districts (D2, D3, D4, and FTE), and somewhat closely with TSM&O staff (18%, or 2 of 11) in other Districts (D4 and D7). However, several project managers (27%, or 3 of 11) reported that construction staff always coordinate with TSM&O staff (D1, D5, and D6).

Of the four participating project managers from D4, the level of interaction with construction staff ranged from somewhat (1 of 4 responses), to very little (2 of 4) and not at all (1 of 4) depending on the position title of each participant, with the greatest interaction occurring with the TSM&O titled participant. However, unlike previous observations of interaction levels by other project development process staff, there was no discernable relationship between project manager position title and greater degree of involvement by construction staff. Survey responses to these questions are listed in Table B.4, Appendix B.

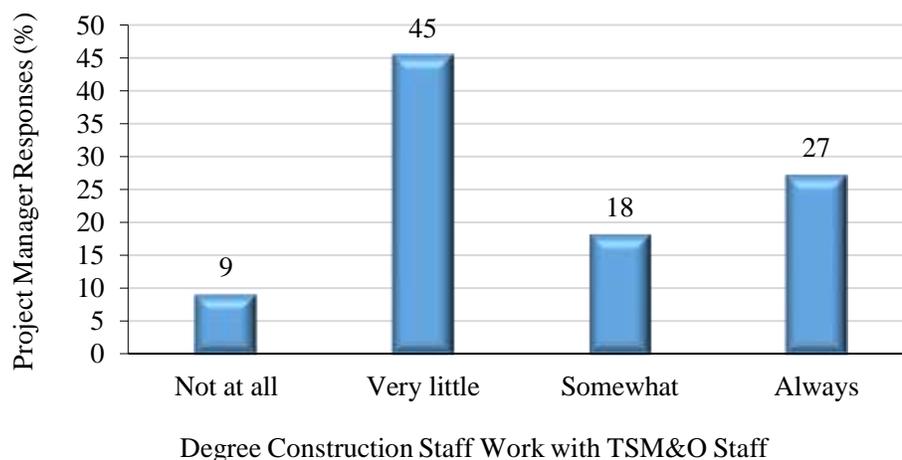


Figure 4.6: Interaction with Construction Staff

4.1.3.5 Overview of Interaction among Staff

An overview of how closely project development staff work with TSM&O staff is shown in Figure 4.7. With the exception of design staff, other project development staff members typically work very little with TSM&O staff, and few Districts experience consistent interaction throughout the project development process.

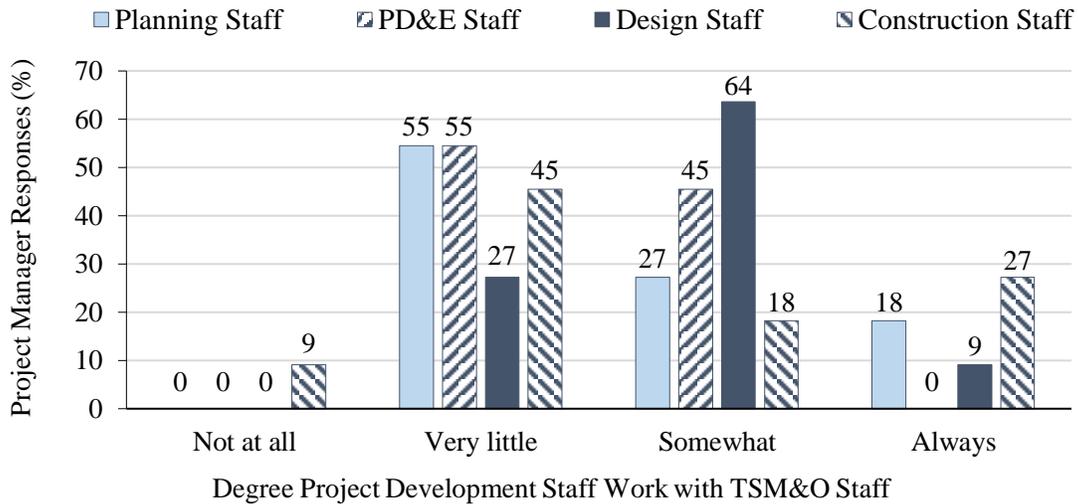


Figure 4.7: Degree Project Development Staff Work with TSM&O Staff

4.1.3.6 Involvement of TSM&O Staff

The survey included several questions related to the involvement of TSM&O staff in the project development process. The first question asked participants if TSM&O staff review potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase. All 11 project managers that participated in the survey replied to this question. Participants, representing each of the seven FDOT districts and the FTE, made one selection from among the following options: Yes, No, Not sure, or Other, to provide additional comments.

As shown in Figure 4.8, four of the eleven participants (36%) indicated that TSM&O staff are involved in the review of projects pre-design (D4, D6, D7 and FTE). However, several project managers stated that this involvement is intermittent (D4 and D6), not systematic (D4), and no formal process exists (D6). Other project managers (36%, or 4 of 11) indicated that TSM&O staff do not review projects for potential opportunities (D1, D2, D5, and one from D4), while (27%, or 3 of 11) were not sure (D3 and two participants from D4). District Five stated that all viable solutions are considered based on purpose and need, including TSM&O strategies.

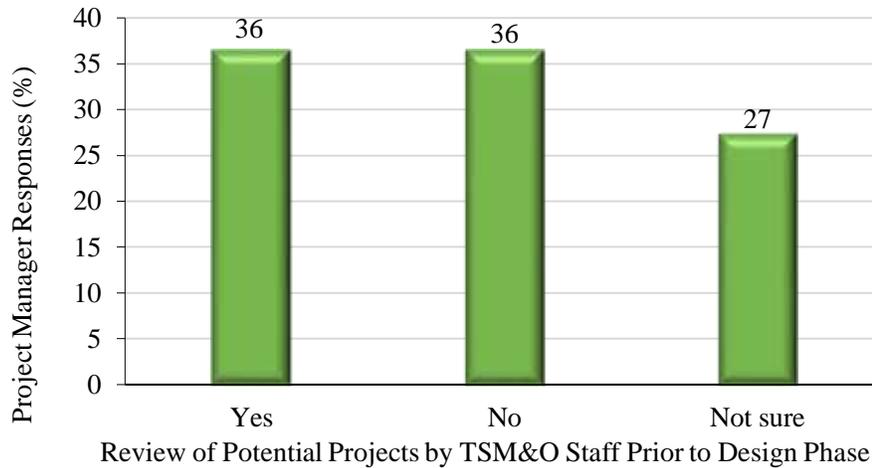


Figure 4.8: Review of Potential Projects by TSM&O Staff

A second question explored how often TSM&O staff are involved in the project development process. Figure 4.9 illustrates the results collected from the 11 project managers that responded to this question. As shown in Figure 4.9, five of the eleven survey participants (45%) indicated that TSM&O staff are more often rarely involved in the project development process (D1, D2, D3, and two project managers from D4), while 36% (4 of 11) stated that TSM&O staff are only involved sometimes (D6, FTE, and two project managers from D4). Few Districts often (D7) or always (D5) include TSM&O staff in the process.

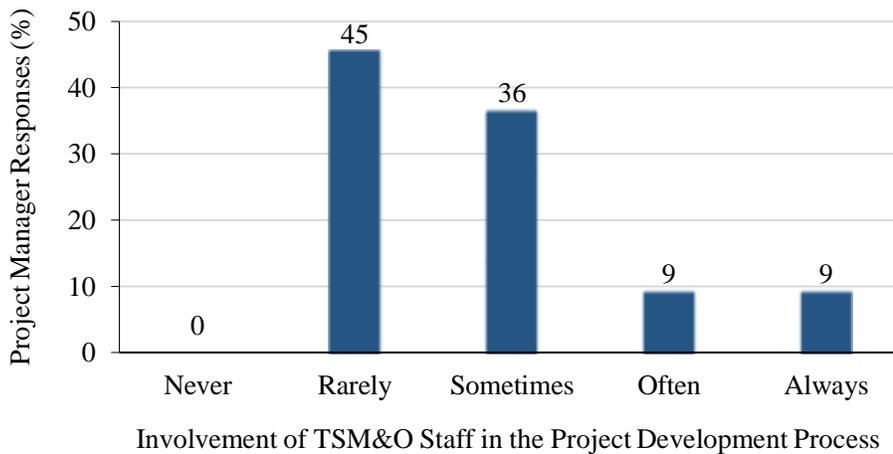


Figure 4.9: Involvement of TSM&O Staff in the Project Development Process

Survey participants were also asked to rate the involvement of traffic operations engineers in the project development process. Figure 4.10 displays the responses of the 11 participating project managers compared with their responses on the involvement of TSM&O staff. Findings indicate that traffic operations engineers are involved in the project development process more often than

TSM&O staff. Over 36% (4 of 11) of project managers described involvement by traffic operations engineers as ‘often’ (D5, D6, D7, and one from D4), with just over 18% (2 of 11) selecting ‘rarely’ (D2 and one from D4). Five of the eleven participants (45%) stated that traffic operations engineers are only sometimes involved in the project development process (D1, D3, FTE, and two from D4), yet no participant selected ‘always’ from the available options. Survey responses to these questions are shown in Table B.5, Appendix B.

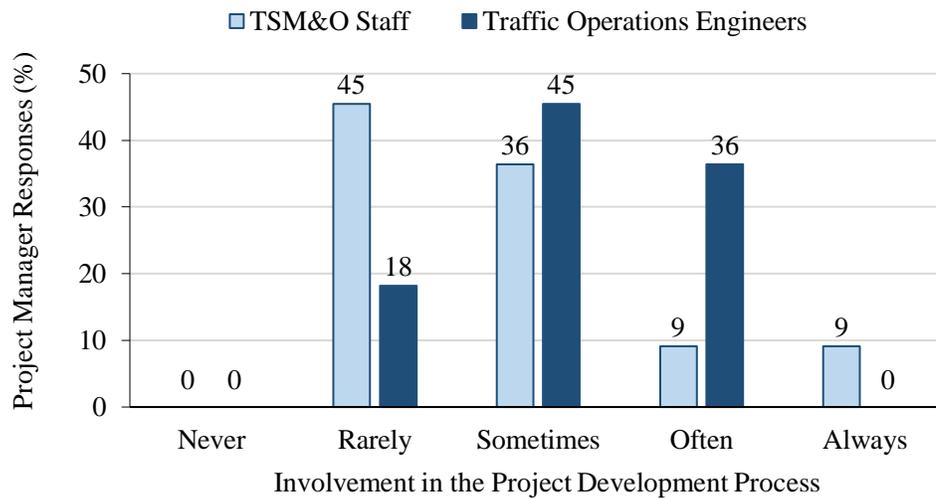


Figure 4.10: Comparison of Involvement by Staff in the Project Development Process

Project managers were also asked whether TSM&O or ITS staff get involved in roadway projects, such as widening, resurfacing, and interstate safety improvements. All 11 survey participants replied to this question. As shown in Figure 4.11, 18% (2 of 11) of participants indicated that TSM&O or ITS staff do get involved in roadway projects (D3 and D5), while nearly 82% (9 of 11) stated that involvement is only sometimes. Responses to this question are listed in Table B.8, Appendix B.

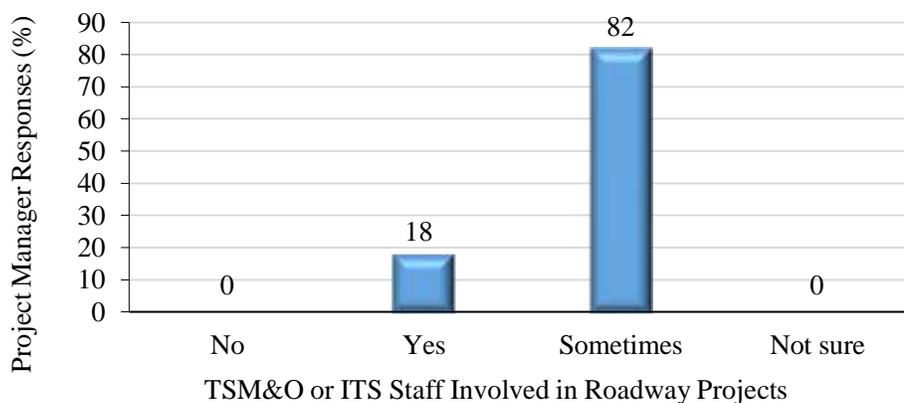


Figure 4.11: Involvement by Staff in Roadway Projects

4.1.4 Constraints When Proposing TSM&O Strategies

Survey participants were asked to list constraints encountered when proposing TSM&O strategies during the project development process. Ten project managers, (D1 through D6, and FTE), replied to this question. No response was obtained from D7. Responses include the following:

- Budget Constraints
- Inadequate funding programmed
- TSM&O involved too late in the process
- Lack of understanding of TSM&O
- Project approach for TSM&O strategies
- Consultants lacking in technical expertise
- No formal process established

Several Districts mentioned project funding as a primary constraint (D1, D2, and D4), especially if TSM&O consideration occurs later in the project development process (D1, D2) or funding for Operations and Maintenance (O&M) is not defined (D4). Other Districts mentioned a general lack of understanding of TSM&O by FDOT staff (D6), and project approach when implementing TSM&O strategies (FTE). Another concern is few consultants having the necessary technical expertise with TSM&O strategies and components (D5). Lack of an established process relating to TSM&O initiatives has also presented constraints during the project development process (D3, D4, and D5). Complete responses to this question are listed in Table B.6, Appendix B.

4.1.5 Project Development Process for TSM&O Projects

To explore the project development process used for TSM&O projects, project managers were asked if the traditional process used for most civil engineering projects is also adopted for TSM&O projects. Ten project managers, (D1 through D6, and FTE), replied to this question. No response was obtained from D7.

Based on comments provided, 70% (7 of 10 responses) of project managers stated that TSM&O projects generally follow the traditional process used by the design office, to some degree (D1, three from D4, D5, D6, and FTE) with the System Engineering (SE) process prevailing once systems are involved (D1 and D6). However, due to the rapid changes in technology, including TSM&O projects in the 5- and 10-year work program is not always practicable. District Two uses a two-year window for applications to upcoming funded projects after examining both existing and near-term technology. Participants from D3 and D4 (1 of 4 respondents) were not sure if the traditional project development process is used for TSM&O projects.

Another question explored how Districts work toward reducing and eliminating delays in the project development and delivery process. Several project managers mentioned that these efforts are outside of their responsibilities (D1, two from D4, and D6), and that reducing and eliminating

delays is typically the responsibility of the lead project manager for each project (D4 and D6), with the TSM&O Office serving as support to the project management staff to meet construction schedules. District Two relies on the Traffic Engineering Research Laboratory (TERL), the Innovative Product Listing, and ITS Expo events to aide in the selection of appropriate technology to meet project needs, and often uses the SE approach for procurement and delivery. Other project managers try to reduce delays by following the process (D5 and FTE). Participants from D3, D7, and one from D4 did not respond to this question. Complete responses for these survey questions are listed in Table B.6, Appendix B.

4.1.6 Experiences Related to TSM&O

To explore the culture surrounding TSM&O activities, survey participants were asked several questions relating to their experiences with others they have worked with, as well as, with executing TSM&O contracts, and previous projects. Ten of the eleven survey participants (D1 through D6, and FTE) replied to these questions. The following sections summarize the findings, with complete responses listed in Table B.7, Appendix B.

4.1.6.1 Experience with Others

The first question asked whether survey participants observed confusion or misunderstanding about TSM&O among FDOT staff or individuals in the private sector. Selection options included: Yes, No, Not sure, and Other, for comments if needed. No response was gathered from D7, however, all other project managers stated ‘yes’, or 100% (10 of 10 responses), that they have observed confusion by others related to TSM&O. This result suggests that an overall lack of understanding about TSM&O is widespread.

4.1.6.2 Executing TSM&O Contracts

A second question asked project managers if they have experienced difficulties in executing TSM&O contracts, and if so, to describe their experiences. Eight of eleven survey participants replied to this question, with D3, one from D4, and D7 project managers not responding. Of those that responded, nearly 88% (7 of 8) indicated that they have experienced issues with executing TSM&O contracts. In contrast, D1 participant stated that they have not experienced such difficulties. Areas of difficulties described by project managers include the following:

- Limited TSM&O expertise in the FDOT and private sector (D2)
- Few contractors and consultants (D4)
- Exclusion of ITS from the planning process (D2)
- Lack of knowledge of ITS by contract reviewers (D4)
- Lack of specifications related to TSM&O and ITS components for contracts (D4)
- Lack of categories for consultant negotiations (D5)
- Lack of understanding projects involving ‘systems’ (D6)
- Implementation of TSM&O as short-term strategy prior to capital improvements (FTE)

4.1.6.3 Previous Projects

Survey participants were also asked if they were involved in a project where a TSM&O strategy may have provided a more cost effective solution in comparison to the conventional capacity expansion method, and to share their experiences. Eight of eleven participating project managers replied to this question, of which 50% (4 of 8) stated ‘yes’, and 50% (4 of 8) replied ‘no’. No response was obtained from D3, one of D4, and D7 survey participants.

Several projects were mentioned where added capacity measures were implemented rather than TSM&O strategies that offered a more cost effective and faster delivery solution. Complete responses are listed in Table B.7, Appendix B.

4.1.7 TSM&O Champions

Survey participants were asked if there is a TSM&O or ITS champion in their District. Ten project managers responded to this question (D1 through D6, and FTE), of which 70% (7 of 10) claimed to have a TSM&O champion in their District (D2, D3, two from D4, D5, D6, and FTE). Two project managers, D1 and one from D4, selected ‘no’, and one project manager from D4 selected ‘not sure’. Interestingly, responses were mixed in D4, the only District with multiple survey submissions by project managers from different groups ranging from TSM&O to Operations and ITS, This result may suggest multiple champions exist in this District, or that the designation of ‘champion’ may have various interpretations.

The rank (level) and title of the top TSM&O staff member in the each District was also requested. Responses, listed in Table 4.2, reveal a variety of position titles and organizational levels among the Districts. Survey responses to this question are shown in Table B.8, Appendix B.

Table 4.2: Rank and Title of Top District TSM&O Staff

District	Rank	Title
1	Career Service	FMS/AMS Specialist IV*
2	Assistant District Traffic Operations Engineer	TSM&O Program Manager
3	<i>No Response</i>	District Traffic Operations Engineer (DTOE)
4	Assistant to a Cost Center Manager (DTOE)	TSM&O Program Engineer
4	<i>No Response</i>	TSM&O Program Manager
4	<i>No Response</i>	District TSM&O Engineer
4	<i>No Response</i>	District TSM&O Engineer
5	<i>No Response</i>	Director of Production

* Arterial Management System (AMS); Freeway Management System (FMS)

Table 4.2: Rank and Title of Top District TSM&O Staff (continued)

District	Rank	Title
6	Executive/Director	Director of Transportation Operations
7	<i>No Response</i>	<i>No Response</i>
FTE	Department Head	District Traffic Operations Engineer (DTOE)

4.1.8 Challenges with TSM&O

Survey participants expressed a number of challenges concerning the implementation of TSM&O in the project development process. Ten project managers responded to this question (D1 through D6, and FTE). Complete responses are listed in Table B.9, Appendix B, and include the following:

- Lack of inclusion of TSM&O by the planning office (D1)
- Limited knowledge by FDOT staff (D2, D6)
- Resistance to adopt TSM&O approach (D2, D4)
- Limited expertise in the industry to support TSM&O efforts (D2, D5)
- TSM&O culture lacking or absent (D3)
- Little focus or importance placed on TSM&O (D4, FTE)
- Lack of resources allocated to TSM&O activities (FTE)
- Poor communication between planning, design, traffic operations (D4)
- Civil engineers unfamiliar with complex ITS infrastructure projects (D4)

Challenges experienced during the construction phase regarding TSM&O components, described by survey participants and listed in Table B.9, Appendix B, include the following:

- Limited expertise in the industry to support TSM&O efforts (D2, D4, D5)
- Classification of ITS as a utility and not as infrastructure (D3)
- Limited budgets for ITS/ Advanced Traffic Management Systems (ATMS) resulting in construction issues (D4)
- Inspectors with lack of knowledge or experience with ITS (D4, D6, FTE)
- Little importance placed on TSM&O components during construction phase (D4, FTE)

4.1.9 FDOT Guidelines

Survey participants were asked to list all FDOT procedural guidelines that should contain TSM&O language. Responses are listed in Table B.9, Appendix B.

The majority of guidelines mentioned were consistent with previously reviewed documents discussed in Chapter 3, as a part of the current TSM&O research effort. Several project managers

mentioned that all FDOT procedural guidelines should address TSM&O or improve the current language. Additional suggestions include the following:

- Revise position title descriptions to include TSM&O/ITS requirements
- Better address procurement processes
- Develop a more rigorous qualification process for consultants and contractors
- Better identify programming funding for future O&M and TSM&O

4.1.10 Summary and Discussion

To determine the extent to which TSM&O is being incorporated in FDOT projects, a survey was conducted to explore the current state-of-the-practice of TSM&O consideration, procedures, and practices at the District level in the FDOT. The survey was administered to project managers in TSM&O, ITS, and Traffic Operations groups in each FDOT District and the FTE. At least one project manager from six of the seven FDOT Districts and the FTE responded to the survey. Four project managers from D4 responded, resulting in a total of 11 survey participants.

Survey results reveal that TSM&O is considered most often during the design and operations phases of the project development process, followed by the planning phase. However, several Districts do consider TSM&O strategies in every phase of the process (D4 (1 of 4 respondents), D6, and D7).

The majority of project managers related to TSM&O/ITS activities generally perceive TSM&O leadership to be present at both the State and District levels in Florida, with eight out of eleven selecting both the Central office and District office options. This indicates that while many aspects of TSM&O activities are managed at the District level, TSM&O leadership in the Central office is also preferred or deemed beneficial. Project managers also generally consider TSM&O staff to primarily work in the traffic operations group and the ITS group within traffic operations. Only a small number of project managers perceive TSM&O staff to work in the planning group.

These results reflect a variety of perceptions, statewide, on when TSM&O activities are considered during the project development process, to which office and work group TSM&O staff should reside. Mainstreaming TSM&O throughout the FDOT would require these elements to be better defined for all project managers involved in TSM&O activities.

Planning staff do engage TSM&O staff in each District and the FTE, however, the degree of interaction is typically very little. Similar results were observed with the interaction between TSM&O staff and PD&E or construction staff. Design staff appear to work somewhat more closely with TSM&O staff; however, few Districts reported consistent interaction with staff of any phase during the project development process. Moreover, survey participants reported a lack of inclusion and little importance placed on TSM&O.

Involvement of TSM&O staff varies by District and by project manager position title, with fewer than half of the Districts, and the FTE, stating that TSM&O staff do review potential projects to determine if TSM&O strategies offer a viable solution. However, this involvement is limited and intermittent in most Districts, and no formal process exists. Although TSM&O/ITS is considered in varying phases of the project development process in each District and the FTE, the level of involvement by TSM&O staff is inconsistent. For example; project managers in D4, D6, and D7 consider TSM&O/ITS in all phases of a project, yet project managers in D4 and D6 are only sometimes involved in the project development process, with the project manager in D7, often involved. Only one TSM&O project manager, D5, responded as always involved in the planning and design phases of the project development process. Additionally, findings indicate that traffic operations engineers are involved in the project development process more often than TSM&O staff.

Although TSM&O consideration is gaining among FDOT culture, TSM&O is often involved too late in the project development process. A formal process for proposing TSM&O strategies is also lacking, thus leading to funding constraints when TSM&O solutions are proposed later in the project development process. A non-defined funding source for O&M continues to pose constraints.

Based on experiences with other FDOT staff or private sector individuals, TSM&O/ITS project managers have observed confusion and misunderstanding, suggesting an overall lack of understanding about TSM&O in the FDOT and the industry. Limited knowledge by FDOT staff may contribute to the resistance to adopt the TSM&O approach and minimize communication between TSM&O staff and other project development staff members.

A considerable challenge for TSM&O project managers is limited expertise in the industry to support TSM&O efforts, and many civil engineers are unfamiliar with complex ITS infrastructure. Successful TSM&O projects require a variety of disciplines outside of Civil Engineering, such as IT, Electrical Engineering, Software Engineering, Industrial Engineering, and statisticians. Limited availability of such experts may stem from a lack of knowledge of planned FDOT TSM&O initiatives. A marketing campaign to better inform project development staff, as well as, existing and potential consultants may be advantageous. A greater focus on promoting this group of planned projects may encourage both the FDOT and industry consultants to staff and prepare accordingly.

Another challenge results from little importance placed on TSM&O components during all phases of project development – planning, PD&E, design, operations, maintenance, and construction. This practice has been notably observed during the construction phase where contractors and inspectors often possess deficient knowledge and experience with ITS infrastructure and components included in the construction plans. Since ITS is a specialized element of roadway construction, this lack of knowledge and experience is understandable; however, to reduce costly future replacement efforts, industry contractors and workers need a

better understanding of TSM&O/ITS elements. An outreach program, initiated by the FDOT, may be beneficial in addressing this issue.

Difficulties in executing TSM&O contracts have also presented challenges, where general lack of knowledge of ITS systems and components exists among consultants and reviewers. Insufficient specifications related to TSM&O and ITS components for contracts, as well as categories for consultant negotiations also contribute to these difficulties.

The variety of survey participants from D4 offered a unique look into the perceptions and experiences of project managers with varying position titles and job descriptions. In almost all cases, responses varied considerably among these participants. Identifying how TSM&O relates to the various work groups in each District would be beneficial toward mainstreaming TSM&O statewide.

Although the majority of participating project managers claim to have a TSM&O champion in their District, others are not sure or state that no designated champion exists. Districts may be organized somewhat differently than the Central Office, however, some organizational guidance to include designated TSM&O champions may prove beneficial in mainstreaming efforts.

4.2 Part II Survey Results

This section focuses on the project delivery, procurement, and payment methods, collectively known as contracting strategies, and system development strategies (i.e., models) that are currently being used by the seven FDOT Districts and the FTE. More specifically, the survey respondents provided example project types for the various project delivery systems, procurement practices, and contract management methods. The respondents were also asked about the different contracting strategies that they think are best suited for TSM&O and ITS projects. Finally, the respondents discussed specific challenges with the system development model(s) that they have adopted for TSM&O/ITS projects.

As mentioned in Chapter 2, project managers from all the seven FDOT Districts and the FTE responded to this survey. Four participants from D4 (Freeway Operations Manager, LCIS Administrator, ITS Operations Manager, and District TSM&O Engineer) completed the survey, resulting in 11 responses. All responses for this part of the questionnaire are summarized in Tables C.1 through C.10 in Appendix C.

For a better presentation of survey responses, all project types provided by the respondents are categorized into the following two broad categories:

- TSM&O/ITS
 - ITS Corridor Deployment Projects
 - ITS Maintenance and Equipment/Devices Projects
 - Truck Parking Availability System (TPAS)
 - Adaptive Traffic Control System (ATCS)
 - Adaptive Signal Control Technology (ASCT)

- Advanced Traveler Information System (ATIS)
- Integrated Corridor Management (ICM)
- Active Traffic Management Projects
- Regional Traffic Management Projects
- Incident Management Systems
- Traffic System Plan and Operations
- Freeway Management System (FMS)
 - Ramp Metering (RM)
 - Express Lanes/Managed Lane Projects (EL)
- Highway/Bridge Construction (HBC)
 - Roadway Improvements/3R Projects
 - Bridge Work Projects

4.2.1 Project Delivery Systems

Project delivery systems are the overall processes by which a project is designed, constructed, and/or maintained. TSM&O/ITS projects benefit from considering more innovative approaches that could potentially improve the speed and efficiency of the project delivery process. As such, one of the survey questions focused on example project types for the project delivery systems currently being used by the Districts. Eight of the eleven responding project managers provided this information. Table 4.3 lists the different project delivery systems that Districts use for TSM&O and ITS, and HBC projects.

Table 4.3: Project Delivery Systems Used by Districts for Different Project Types

Project Delivery System	Type of Project
Design-Build	TSM&O and ITS, HBC
Design-Bid-Build	TSM&O and ITS
Design Sequencing	N/A
Indefinite Delivery/Indefinite Quantity (ID/IQ)	N/A
Agency-Construction Manager	N/A
Construction Manager at-Risk	TSM&O and ITS
Contract Maintenance	TSM&O and ITS

Table 4.4 summarizes the different project delivery systems currently being used in each District for TSM&O/ITS projects. Note that the project manager from D7 did not respond to this question. As can be observed from Table 4.4, all of the responding project managers use the Design-Build project delivery system. Design-Bid-Build and Contract Maintenance are the next most common project delivery systems. None of the responding project managers use Design Sequencing, Indefinite Delivery/Indefinite Quantity (ID/IQ), or Agency-Construction Manager delivery methods for TSM&O/ITS projects. The Construction Manager at-Risk delivery method is only used by the project manager from D2. Moreover, project managers from D2, D4, and D5 mentioned that they use “other” types of delivery systems for their TSM&O/ITS projects. The project manager from D2 stated that they use “A System Manager whereby the design firm

provides plans, the Department purchases equipment, contractor deploys infrastructure, design firm integrates with Department staff”. The project manager from D2 also stated that this approach will result in a product that is as desired, on-time, and under budget. The project manager from D4 stated that they use “other” project delivery system for asset maintenance of a roadway, which includes the Road Ranger service. The project manager from D5 stated that they use Invitation to Negotiate (ITN) for Integrated Corridor Management (ICM) projects, Invitation to Bid (ITB) for IT hardware, and Design-Build-Operate-Maintain (DBOM) for State Road 40 construction projects.

Table 4.4: Summary of Project Delivery Systems Used by Districts

Project Delivery Systems	D1	D2	D3	D4	D5	D6	D7	FTE
Design-Build	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes
Design-Bid-Build	-	Yes	-	Yes	Yes	Yes	-	Yes
Design Sequencing	-	-	-	-	-	-	-	-
Indefinite Delivery/Indefinite Quantity	-	-	-	-	-	-	-	-
Agency-Construction Manager	-	-	-	-	-	-	-	-
Construction Manager at-Risk	-	Yes	-	-	-	-	-	-
Contract Maintenance	-	Yes	-	Yes	Yes	Yes	-	Yes
Other	-	Yes	-	Yes	Yes	-	-	-

Since a Design-Build contract may also include responsibilities such as warranty, maintenance, operations, etc., the following delivery systems are becoming increasingly popular:

- Design-Build-Warranty
- Design-Build-Maintain
- Design-Build-Operate
- Design-Build-Operate-Maintain

Table 4.5 summarizes the different Design-Build systems currently being used in each District for TSM&O/ITS projects. Of the different Design-Build systems, Design-Build-Warranty is the most common system, and is used by the project managers from five Districts. None of the project managers stated that they use Design-Build-Operate system for their TSM&O/ITS projects. Note that the project managers from D4 and D6 use more than one Design-Build delivery system.

Project managers from D1, D4, and FTE consider Design-Build to be the best project delivery system for TSM&O/ITS projects. Their reasons for this preference are as follows:

- With limited FDOT liability, puts all responsibility on the Design-Build contractor; adjusted score grading makes the contractor propose qualified personnel and high quality construction concepts; often comes with extended warranties. (D1)
- If done correctly and executed as written, Design-Build method can be the most successful. However, Design-Build projects will not have a TSM&O Design project

manager, nor a TSM&O Construction project manager. FDOT management decided that all offices should focus on core business. The practice of TSM&O staff as Design project manager was stopped. (D4)

- Only if the project is a stand-alone TSM&O/ITS project; otherwise, prefer Design-Bid-Build. (FTE)

Table 4.5: Summary of Different Design-Build Systems Used by Districts

District	Design-Build-Warranty	Design-Build-Maintain	Design-Build-Operate	Design-Build-Operate-Maintain
D1	Yes	-	-	-
D2	Yes	-	-	-
D3	-	-	-	Yes
D4	Yes	Yes	-	Yes
D5	-	-	-	-
D6	Yes	-	-	Yes
D7	-	-	-	-
FTE	Yes	-	-	-

The project manager from D6 prefers Design-Bid-Build because it provides the owner the ability to clearly define requirements and expectations. The project manager from D5 also prefers Design-Bid-Build because they are familiar with this system; although also states that the method should fit the project. The project manager from D2 prefers a System Manager because this method provides flexibility, lower costs, and the most current technology. The project manager from D3 prefers Bill of Materials for TSM&O/ITS projects. Survey responses to these questions are shown in Tables C.2 and C.3, Appendix C.

4.2.2 Procurement Practices

Procurement practices are the overall procedures by which a project is to be evaluated for the selection of designers, contractors, and various consultants. Project managers from four Districts (D1, D2, D4, and D5) provided example project types for the following procurement practices:

- Cost-Plus-Time Bidding (A+B)
- Multi-Parameter Bidding (A+B+C)
- Lump Sum Bidding
- Alternate Design
- Alternate Bid
- Additive Alternates
- Best-Value Procurement
- Bid Averaging

Table 4.6 summarizes the different procurement practices currently used in each District. Project managers from three Districts (D1, D2, and D5) use Lump Sum Bidding to procure TSM&O/ITS

projects. Cost-Plus-Time Bidding (A+B) and Best-Value Procurement methods are the next most common procurement practices. None of the responding project managers use Multi-Parameter Bidding (A+B+C) and Alternate Design methods. Note that project managers from D3, D6, D7, and FTE did not respond to this question. Project managers from D2, D4, and D5 stated that they use the following procurement practices for TSM&O/ITS projects:

- A System Manager (D2)
- Adjusted score that factors price, schedule, and technical score (D4)
- Low-Bid for Transportation System Plan (TSP) projects (D5)

Table 4.6: Summary of Different Procurement Practices Used by Districts

Procurement Practices	D1	D2	D3	D4	D5	D6	D7	FTE
Cost-Plus-Time Bidding (A+B)	-	-	-	Yes	Yes	-	-	-
Multi-Parameter Bidding (A+B+C)	-	-	-	-	-	-	-	-
Lump Sum Bidding	Yes	Yes	-	-	Yes	-	-	-
Alternate Design	-	-	-	-	-	-	-	-
Alternate Bid	Yes	-	-	-	-	-	-	-
Additive Alternates	-	-	-	-	Yes	-	-	-
Best-Value Procurement	Yes	-	-	-	Yes	-	-	-
Bid Averaging	-	Yes	-	-	-	-	-	-
Other	-	Yes	-	Yes	Yes	-	-	-

One of the survey questions focused on what the project managers consider the best procurement method for TSM&O and ITS projects. The project manager from D1 prefers Lump Sum Bidding, stating the following reasons for this preference: *“They are predictable and easier to manage because of their relative simplicity. Limits FDOT’s financial exposure during construction. Provides a relative amount of cost certainty. Contractor typically provides better management of contract to stay within budget. Needs good oversight to ensure compliance with requirements, otherwise contractor could cut corners to increase profit.”* The project manager from D3 considers Best-Value Procurement to best suit TSM&O/ITS projects, reasoning that value is more important for these types of projects. Several project managers from D4 believe that the Cost-Plus-Time Bidding (A+B) method is most suitable for TSM&O/ITS projects, stating that it can work well, especially if the processes are followed by the other project managers involved. Multi-Parameter Bidding (A+B+C) was selected by the D6 project manager based on the reasoning that *“quality needs to be part of the equation when dealing with systems”*.

4.2.3 Contract Management Methods

Contract management methods are the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. Project managers from five of the eight responding Districts provided example project types for the following contract management methods:

- Incentives/Disincentives (I/D) Provisions for Early Completion

- Lane Rental
- Flexible Notice to Proceed Dates
- Liquidated Savings
- Active Management Payment Mechanism (AMPM)
- No Excuse Incentives

Table 4.7 summarizes the different contract management methods used by each District. As can be observed from Table 4.7, none of the Districts use Lane Rental, Flexible Notice to Proceed Dates, Liquidated Savings, Active Management Payment Mechanism (AMPM), or No Excuse Incentives contract management methods. One project manager from D4 uses Incentives/Disincentives (I/D) Provisions for Early Completion method, particularly for Managed Lane projects. The project manager from D6 stated that this method (i.e., Incentives/Disincentives (I/D) Provisions for Early Completion) typically leads to “cutting corners” (e.g., watered down testing, acceptance of subpar projects, etc.). No response was obtained from D3, D7, or the FTE.

Table 4.7: Summary of Contract Management Methods Used by Districts

Project Delivery System	D1	D2	D3	D4	D5	D6	D7	FTE
Incentives/Disincentives	-	-	-	Yes	-	Yes	-	-
Lane Rental	-	-	-	-	-	-	-	-
Flexible Notice to Proceed Dates	-	-	-	-	-	-	-	-
Liquidated Savings	-	-	-	-	-	-	-	-
Active Management Payment Mechanism	-	-	-	-	-	-	-	-
No Excuse Incentives	-	Yes	-	-	-	-	-	-
Other	Yes	Yes	-	-	Yes	-	-	-

Project managers from four of the responding Districts were not sure which contract management method is best suitable for TSM&O/ITS projects. However, the project manager from D2 stated that having a System Manager who sets delivery date and ensures the final product meets the intent of the project is the best approach to conduct TSM&O/ITS projects. Additionally, project managers from D4 and D5 stated that none of the contract management methods listed in Table 4.7 are appropriate for TSM&O/ITS projects.

4.2.4 Funding Sources for TSM&O Projects

Project managers from six Districts provided information about funding sources for their TSM&O projects. The funding source selection options available in the survey included:

- Congestion Mitigation and Air Quality Improvement (CMAQ) Program
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- National Highway Performance Program (NHPP)
- Transportation Investment Generating Economic Recovery (TIGER)
- Highway User Revenue Fund

- Local Taxes
- Unified Planning Work Program (UPWP)
- Public-Private Partnership

Table 4.8 summarizes the Districts’ funding sources for TSM&O projects. Although one project manager from D4 was not sure of the funding sources used by the District for TSM&O activities, it was mentioned that a better understanding is needed regarding funds that can be used for TSM&O and the utilization of those funds (i.e., capital vs. O&M). Responses to this question were not obtained from D3 and D7.

Table 4.8: Funding Sources for TSM&O Projects

Funding Sources	D1	D2	D3	D4	D5	D6	D7	FTE
Congestion Mitigation and Air Quality Improvement Program	-	Yes	-	-	-	-	-	-
Surface Transportation Program	-	Yes	-	-	Yes	-	-	-
Highway Safety Improvement Program	Yes	Yes	-	-	Yes	-	-	-
National Highway Performance Program	-	-	-	-	-	-	-	-
Transportation Investment Generating Economic Recovery	-	-	-	-	-	-	-	-
Highway User Revenue Fund	Yes	-	-	-	-	-	-	-
Local Taxes	-	Yes	-	-	Yes	-	-	-
Unified Planning Work Program	-		-	-	Yes	-	-	-
Public-Private Partnership	-		-	-	Yes	Yes	-	-
Other	-	a	-	b	c	-	-	d

^a State funds; ^b Not sure; ^c District funds; ^d Toll revenue.

Project managers from D6 and FTE stated that dedicated funding is set aside for TSM&O projects, while project managers from D4 and D5 allow TSM&O projects to compete with other types of projects for funding. Project managers from D1 and D2 combine a set-aside funding source, with the ability for TSM&O projects to compete for other funding. One project manager from D4 mentioned that they follow ad-hoc strategies for construction.

4.2.5 System Development Strategy

This section discusses the system development strategies that are currently being adopted by the Districts for TSM&O/ITS projects. The most commonly used system development models include:

- Waterfall Model
- Agile Model
- Incremental Build Model
- Spiral Model

Table 4.9 summarizes the different system development models currently being used by each District for TSM&O/ITS projects. As can be observed from Table 4.9, the Waterfall model is the most commonly used model. Project managers from D1, D4, D5, and D6 stated that they use this system development strategy. The project manager from D2 uses the Agile Model, while D5 also uses the Agile model, as well as the Incremental Build model. Note that none of the responding project managers stated that they use the Spiral model for their TSM&O/ITS projects.

Table 4.9: Summary of System Development Strategies Used by Districts

District	Waterfall Model	Agile Model	Incremental Build Model	Spiral Model	Other
D1	Yes	-	-	-	-
D2	-	Yes	-	-	-
D3	-	-	-	-	-
D4	Yes	-	-	-	-
D5	Yes	Yes	Yes	-	-
D6	Yes	-	-	-	-
D7	-	-	-	-	-
FTE	-	-	-	-	-

Survey respondents mentioned the following challenges they experience with their current system development model for TSM&O/ITS projects:

- Professionals reluctant to embrace technology. (D2)
- Lack of resources and designated funding. (D3)
- Lack of upper management and staff level understanding for how systems work individually and with other systems. An Express Lanes project will only work if the ITS and Tolling system works, but the system is not the biggest expense so it does not get the same attention as the bigger ticket items. How systems are to be planned for, designed, how they operate and how they should be maintained is not understood outside of TSM&O experts. (D4)
- Prequalification. (D5)
- Resistance from other FDOT offices due to lack of understanding of systems engineering. (D6)

4.2.6 Summary

A two-part online survey was administered to project managers in TSM&O, ITS, and Traffic Operations groups in each FDOT District and the FTE. Part I of the questionnaire explored the current state-of-the-practice of TSM&O in the Districts' project development process, while Part

It focused on the project delivery systems, procurement practices, contract management methods, and system development strategies (i.e., models) that are currently being used by the Districts for TSM&O/ITS projects.

Of the different types of project delivery systems, Design-Build is most commonly used, followed by Design-Bid-Build and Contract Maintenance systems. Among the different types of Design-Build delivery systems, Design-Build-Warranty is the most common system. Project managers from three Districts stated that they use Lump Sum Bidding method to procure TSM&O and ITS projects. Project managers from only a couple of Districts have adopted the contract management methods included in the survey for their TSM&O/ITS projects. Project managers from four of the eight responding Districts stated that they use the Waterfall development model for their TSM&O and ITS projects.

Table 4.10 lists the most suitable contracting strategies (i.e., project delivery method, procurement practices, and the contract management methods) for TSM&O/ITS projects at the FDOT District level, as identified by the survey respondents. As can be observed from Table 3.8, project managers from several Districts consider Design-Bid-Build and Design-Build delivery methods to be more suitable for TSM&O/ITS projects. Conversely, project managers from no two Districts identified the same procurement method for procuring TSM&O/ITS projects. Furthermore, none of the responding project managers selected any of the contract management methods available in the survey.

Table 4.10: Most Suitable Contracting Strategies Identified by Districts

District	Project Delivery Method	Procurement Method	Contract Management Method
D1	Design-Build	Lump Sum Bidding	Not Sure
D2	Other: A System Manager	Other: A System Manager	Other: A System Manager
D3	Other: Bill of Materials	Best-Value Procurement	Not Sure
D4	Design-Build	Cost-Plus-Time Bidding	None from this list
D5	Design-Bid-Build	Other: Low Bid	None from this list
D6	Design-Bid-Build	Multi-Parameter Bidding	Not Sure
D7	-	-	-
FTE	Design-Build	Not Sure	Not Sure

- No Response.

5 – DISTRICT SURVEY II

An online survey questionnaire consisting of a variety of TSM&O aspects was administered to staff from other areas, such as design, planning, PD&E, and construction, in each of the eight FDOT Districts, including the Florida Turnpike Enterprise (FTE), in December 2016. Information requested in the survey is provided in Appendix D.

The questionnaire explored both general and specific information related to TSM&O practices. Questions ranging from the general understanding of TSM&O, its inclusion in project phases, and challenges with TSM&O implementation were asked.

5.1 Survey Results

Survey responses were received from project managers outside of TSM&O, ITS, and Traffic Operations in four districts, District One (D1), District Two (D2), District Four (D4), and District Five (D5), for a total of 13 participants. Position titles varied among these participants with seven of the thirteen participants most often involved in the planning phase of the project development process, and four of the thirteen most often involved in the design phase. One Freight Logistics and Passenger Operations (FLPO) manager (D2), one construction project manager (D5), and one project manager involved in multi-modal development (D5), also participated in the survey. All responses from the survey questionnaire are provided in Tables E.1 through E.11 in Appendix E. Missing responses to questions are marked as *No Answer*.

5.1.1 TSM&O in the Project Development Process

Survey participants were asked to select each project development process phase that TSM&O is generally considered in their District. The options provided in the survey included Planning, Design, Construction, Operations, None, and Not sure. All 13 participants replied to this question. Results, listed in Table E.1, Appendix E, and illustrated in Figure 5.1, reveal that the majority of responding project managers perceive that TSM&O consideration occurs primarily during the planning phase (92%, or 12 of 13 project managers), and the design phase (85%, or 11 of 13 project managers).

Consultant project managers in both D4 and D5, typically involved in design, indicated that TSM&O is most often included during the planning and design phases, while project managers typically involved in planning, responded that TSM&O is most often included during the planning, design, and operations phases. The construction project manager in D5 responded that TSM&O is only considered during the design phase of the project development process.

Several project managers, two from D4, and two from D5, indicated that TSM&O is included in all phases of the project development process within the District. Of the D4 project managers, one is usually involved in design, while the other is typically involved in planning. Of the D5 project managers, one is typically involved in planning, and one is involved in multi-modal development. These results highlight the varying degree of inclusion of TSM&O in the project development process, not only among Districts, but also dependent on phase involvement of the project managers. Survey responses to this question are shown in Table E.1, Appendix E.

Interestingly, when questioned how often TSM&O is considered in their respective involvement phase from the options of *Never*, *Rarely*, *Sometimes*, or *Always*, 86% (6 of 7 respondents) indicated that TSM&O is only sometimes considered (D4 and D5), and 14% (1 of 7) indicated that TSM&O is rarely considered (D4). No response to this question was obtained from D1, D2, and two participants from D5. Refer to Table E.3, Appendix E, for survey responses.

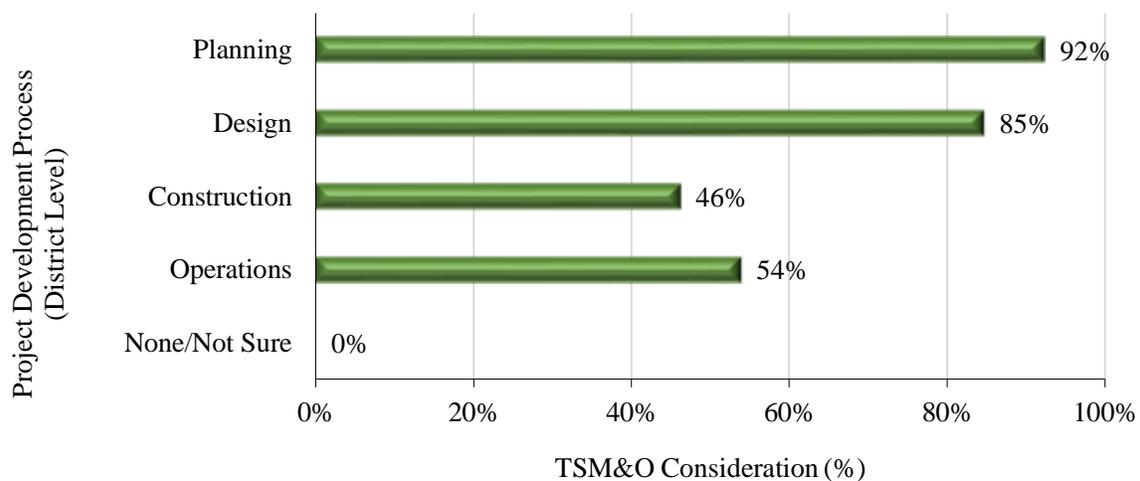


Figure 5.1: District Level TSM&O Consideration in the Project Development Process

5.1.2 Importance of TSM&O

Survey participants were asked to rate the importance of TSM&O in the project development process. All thirteen participating project managers responded to this question. Results, shown in Figure 5.2, and listed in Table E.5, Appendix E, indicate that, overall, the majority of project managers consider TSM&O to be very important (69%, or 9 of 13 respondents). Three of thirteen participants (23%) deem TSM&O to be somewhat important (D4), while one project manager considers it to be only a little important (D4).

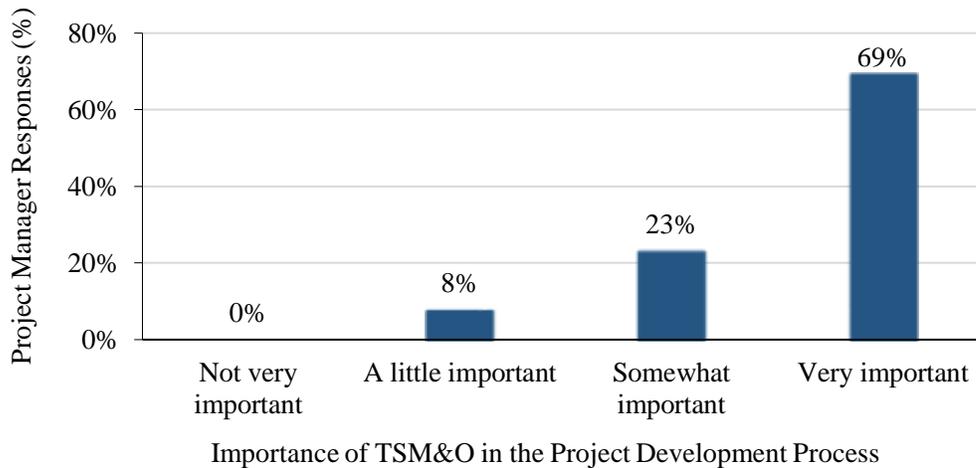


Figure 5.2: Importance of TSM&O in the Project Development Process

5.1.3 Interaction with TSM&O Staff

Survey respondents were asked if they engage TSM&O staff in their District, and if so, to explain the process by which they interact. Twelve participants responded to this question, with all twelve indicating that they do engage TSM&O staff in their District. However, the process and degree of interaction with TSM&O staff varies considerably among the different project managers.

Two planning managers in D4 mentioned that they interact with TSM&O staff during scope development or with new planning studies, while another (D4) stated that interaction is “a reactive mode when typical capacity options have been exhausted”. Several project managers coordinate with other work groups (D1), especially traffic operations (D2, D4, and D5). One survey participant in D4 commented that no known process exists for engaging TSM&O staff, while another project manager (D4) interacts with TSM&O staff during the development of Maintenance of Traffic (MOT) plans to evaluate alternatives. One project manager in D2 mentioned that their “ITS Coordinator is involved in the scope process” of projects, while the other D2 project manager states that their group only focuses on TSM&O aspects for bus rapid transit projects. These results suggest that the level of interaction with TSM&O staff depends greatly on the project development phase to which each project manager is typically involved, as well as, the project managers involved in the project. Complete responses to this survey question are shown in Table E.3, Appendix E.

5.1.4 Understanding of TSM&O and Training

Survey participants were asked to rate their overall level of understanding of TSM&O, from the following options: A great deal, A lot, A moderate amount, A little, or None at all. All thirteen survey participants responded to this question. Illustrated in Figure 5.3, results reveal that 54% (7 of 13) of participants understand TSM&O a moderate amount, and 38% (5 of 13) only have a little understanding. Only one participant, a Transportation Planning Manager in D5, indicated a great deal of understanding of TSM&O. Survey responses to this question are shown in Table E.4, Appendix E.

The degree of training or education that project managers and staff from other groups have received related to TSM&O corresponds with the level of understanding of TSM&O specified by the survey respondents (refer to Figure 5.3). As shown in Figure 5.4 and listed in Table E.5 of Appendix E, 38% (5 of 13) of participants indicated that they have received previous training/information related to TSM&O in the way of workshops, presentations, meetings, informational flyers, independent research, or discussions with TSM&O experts in their District. In contrast, nearly 62% (8 of 13) have received no training. Interestingly, one project manager in D2 has attended a number of workshops and presentations, yet indicates an overall level of understanding of TSM&O as a moderate amount. On the other hand, the project manager (D5) with a great deal of understanding attends bi-monthly TSM&O consortium meetings and meets weekly with traffic operations staff and consultants to discuss TSM&O objectives in their District.

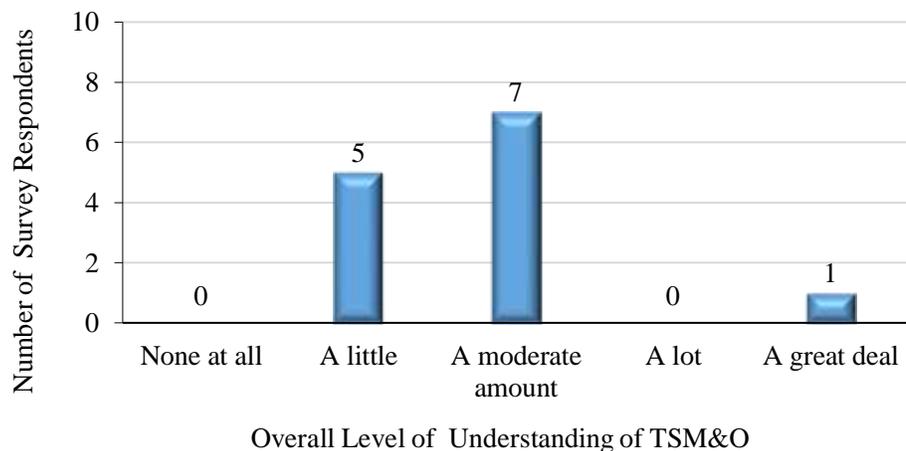


Figure 5.3: Overall Level of Understanding of TSM&O

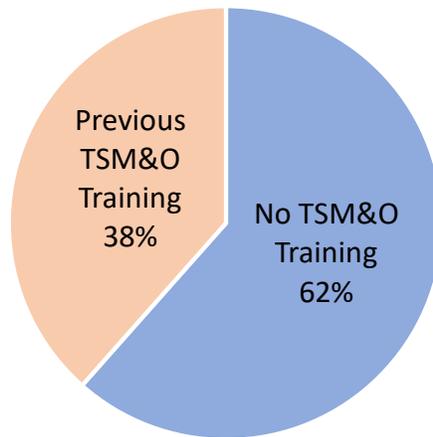


Figure 5.4: TSM&O Training

Areas of additional TSM&O training that project managers felt are needed include:

- All areas of TSM&O (D1, D2, D4)
- General and technical overview (D4)
- Benefits and best practices (D4)
- TSM&O strategies and cost estimations (D4)

One D4 project manager also mentioned the need for understanding “the types of expertise needed to help identify appropriate strategies”, such as computer and electrical engineering. In D5, one project manager responded as needing no additional training, while another was not sure. The remaining two D5 participants and one D2 participant did not respond to this question. Complete responses are listed in Table E.8, Appendix E.

5.1.5 Systems Engineering Process

Survey participants were asked several questions relating to the use of the Systems Engineering (SE) process and development of SE documents. As shown in Table E.6 of Appendix E, all thirteen participants responded to these questions.

Nearly 85% (11 of 13 participants) responded as having never used the SE process for ITS components on projects. The remaining two participants (15%, or 2 of 11) answered as not sure. Correspondingly, when asked how often SE documents are developed, 69% (9 of 13) stated that they do not use the SE process, while nearly 31% (4 of 13 participants) responded as not sure.

5.1.6 TSM&O Concept Development

Survey participants were asked several questions relating to the development and experiences of TSM&O project concepts. Project managers were also asked to share their thoughts on how

projects should be planned for while considering TSM&O. The following sections summarize the findings, with complete responses listed in Tables E.7 and E.8, Appendix E.

5.1.6.1 Development of TSM&O Concepts

Project managers were asked to describe how they develop TSM&O project concepts. Survey respondents who previously stated as being most often involved in the design phase responded to this question as having no experience with TSM&O concept development (D4) or as generally referring to the TSM&O, ITS or Traffic Operations staff in their District (D4 and D5). The construction project manager (D5) also mentioned that TSM&O concepts are developed during the design phase and incorporated in the construction phase.

Survey participants most often involved in the planning phase of the project development process develop TSM&O project concepts by assessing and prioritizing needs (D4), coordinating with design and operations staff (D5), and promoting TSM&O with MPOs. District Two project managers develop TSM&O concepts at the planning level for corridor studies or Master Plans. District Four is also in the process of developing a TSM&O Master Plan for two of the five counties in the District.

5.1.6.2 Challenges Experienced

Roadblocks or issues experienced by project managers when implementing TSM&O concepts included the following:

- No established process to vet TSM&O options (D4)
- Lack of knowledge or training on TSM&O (D4)
- Funding for operations and maintenance (D2, D4, D5)
- Addressing TSM&O late in project development process resulting in additional time and money (D5)

One D4 project manager reported no difficulties when including TSM&O concepts in projects. The construction project manager in D5 stated that the design group usually handles TSM&O concept elements. No response was obtained from D1 and one participant from D2.

5.1.6.3 Planning Suggestions

Survey participants were asked to share their thoughts on how projects should be planned for while considering TSM&O. Suggestions provided by project managers include the following:

- TSM&O should be considered for all or most projects (D4)
- TSM&O should be considered during all phases of a project (D4)
- TSM&O should be incorporated in the early phases of a project (D2, D5)
- TSM&O should be incorporated during PD&E and Design Scoping (D5)
- TSM&O should be added to the Scope of Services of a project (D2)

D1 project manager mentioned that a better understanding is needed for TSM&O consideration at the planning level. One project manager in D4 also added that the management of transportation systems alone “won’t solve oversaturated flow conditions”.

5.1.7 TSM&O Project Experience

Survey participants were asked if they were involved in a project that used a TSM&O strategy, and if so, to describe their experiences. Nine of eleven participants responded ‘yes’, that they have been involved in such a project, while one of eleven stated ‘no’, and the remaining one respondent stated ‘not sure’. Projects and/or TSM&O strategies provided by the participating project managers include the following:

- Adaptive signal systems (D1, D4)
- Advanced Traffic Management Systems (ATMS) (D4)
- Indiantown Road (D4)
- I-95 Express Lanes (D4)
- Interstate Master Plans (D2)

5.1.8 Construction Experiences

The final six questions of the survey pertained primarily to construction project managers. Responses are listed in Tables E.9 through E.11 in Appendix E. Although only one construction project manager (D5) participated in the survey, many of the design and planning project managers also responded to these questions. Results are summarized in following sections.

5.1.8.1 Installation and Testing of ITS Components

Construction project managers were asked to describe their experiences with the field installation of ITS components. The construction project manager in D5 stated that power infrastructure is often not considered by designers, and ITS components are “frequently outdated and/or unavailable” due to rapid advances in technology. Several consultant project managers also commented that field installation has been successful (D5), and that lack of knowledge of ITS components has made integrating pay items into construction documents difficult (D4). Many of the remaining survey participants expressed no experience with field installation of ITS components.

A second question referred to experiences during the unit/device testing of ITS components. The construction project manager in D5 mentioned that a good working relationship exists with traffic operations staff in the District to test completed systems. All other survey participants involved in planning and design phases expressed no experience in this area of the project development process.

5.1.8.2 System Verification and Validation

Construction project managers were asked to describe their experiences during subsystem or system verification and deployment, as well as during system validation. No response was obtained, for either question, from the only construction project manager (D5) that participated in the survey. All other project managers involved in planning and design phases expressed no experience with system verification or validation.

5.1.8.3 Additional Assistance Needed

Construction project managers were asked how TSM&O staff should assist during the validation process. The construction project manager participant (D5) commented that TSM&O staff should be involved; however, no other suggestions as to how they should assist were offered. Other project manager participants, typically involved in planning and design phases, expressed uncertainty or no experience.

A second question asked if construction staff needed more tools to determine if TSM&O requirements are met. No response for this question was obtained from the construction project manager (D5) that participated in the survey. Other project manager participants, typically involved in planning and design phases, expressed uncertainty or no experience.

5.1.9 Preliminary Recommendations

Based on the survey results, the following recommendations may be beneficial in mainstreaming TSM&O throughout the FDOT:

- General training about TSM&O for all disciplines.
- Continuing education efforts in the way of regular meetings, as feasible, for project managers in all disciplines on TSM&O aspects and implementation efforts at the District level and statewide.
- Initiate a “Think TSM&O” campaign throughout the agency to not only improve the culture, but also to express the importance and benefits of TSM&O in Florida.
- General training on the SE process for all disciplines.
- Language included in FDOT guidelines, as appropriate, to promote the use of the SE process on applicable projects, especially on FHWA funded projects.
- For each project, TSM&O should be included as one of the alternatives, and TSM&O elements within the remaining alternatives should also be considered.

5.2 Chapter Summary and Discussion

To determine the extent to which TSM&O is being incorporated in FDOT projects, a survey was conducted to explore the current state-of-the-practice of TSM&O consideration, procedures, and practices at the District level in the FDOT. The survey was administered to project managers and staff outside of TSM&O, ITS, and Traffic Operations groups in each FDOT District and the

FTE. Survey responses were received from project managers in four districts, District One (D1), District Two (D2), District Four (D4), and District Five (D5), for a total of thirteen participants.

Position titles varied among these participants with seven of the thirteen participants most often involved in the planning phase of the project development process, and four of the thirteen, most often involved in the design phase. One FLPO manager (D2), one construction project manager (D5), and one project manager involved in multi-modal development (D5), also participated in the survey.

Survey results reveal that TSM&O is considered most often during the planning and design phases of the project development process, followed by the operations phase. Few project managers, two from D4, and two from D5, indicated that TSM&O is included in all phases of the project development process within their District.

Although 69% (9 of 13 project managers) consider TSM&O to be very important in the project development process, and 23% (3 of 13 respondents) consider it to be somewhat important, 86%, or 6 of 7 survey participants, indicated that TSM&O is only sometimes considered (D4 and D5), and 14% (1 of 7) indicated that TSM&O is rarely considered (D4) in project types they are most involved with. These results reveal that significant efforts are needed to improve the culture of TSM&O consideration throughout the project development process.

Ten survey participants responded that they do engage TSM&O staff in their District. However, the process and degree of interaction with TSM&O staff varies considerably among the different project managers. The level of interaction depends greatly on the project development phase to which each project manager is typically involved, as well as, the persons involved. These findings indicate that a more formalized interaction process may be beneficial in mainstreaming TSM&O within the agency.

In general, project managers outside of TSM&O, ITS, and Traffic Operations also possess a limited level of understanding of TSM&O. Over half of the respondents (54%, or 7 of 13) claim to have only a moderate amount of understanding. These results are not surprising since 62% (8 of 13 participants) reported having had no training on TSM&O. This lack of knowledge may be a leading factor in why TSM&O consideration is often minimized at various phases of the project development process.

Questions pertaining to the use of systems engineering (SE) revealed that project managers outside of TSM&O, ITS, and Traffic Operations have very little exposure to the process. Nearly 82% (9 of 11) of respondents stated that they have never used the SE process, and nearly 85% (11 of 13) claimed that they do not use the SE process. Interestingly, over half (combined question responses) of the respondents indicated that they were “not sure” if they have used the process or developed SE documents. These results further reveal a limited knowledge of TSM&O aspects by project managers outside of TSM&O/ITS or traffic operations.

Development of TSM&O concepts also vary among the different types of project management. Project managers that are typically involved in the design phase of the project development process responded as having no experience with TSM&O concept development, and generally refer to TSM&O staff in their District. Alternatively, project managers typically involved in the planning phase of the project development process have more experience with TSM&O concept development. Funding for operations and maintenance, as well as, lack of knowledge and TSM&O training are the primary challenges experienced with implementing TSM&O concepts. A number of participants also believe that TSM&O should be considered for all projects and during all phases of the project development process.

Findings from questions related to ITS components and system verification and validation that pertained primarily to construction project managers are inconclusive since only one participant in construction management (D5) responded to the survey. However, the construction project manager in D5 did state, in reference to field installation of ITS components, that power infrastructure is often not considered by designers, and ITS components are “frequently outdated and/or unavailable” due to rapid advances in technology. The majority of all other project managers that participated expressed no experience in this area of the project development process. Additionally, the question on how TSM&O staff should assist during the system validation process appears to have been misinterpreted by all of the survey participants.

Based on the survey responses, training on the general aspects of TSM&O is needed for all disciplines. Additional training on the SE process would also be beneficial. To mainstream TSM&O effectively throughout the FDOT, more efforts are needed to inform and educate project managers and staff outside of TSM&O, ITS, and Traffic Operations groups on the importance and benefits of TSM&O in Florida.

6 – NATIONWIDE DOT SURVEY

A two-part online survey questionnaire was administered to State DOT officials in each U.S. State, including Florida. Prior to the survey launch in April 2016, contact information was gathered from DOTs websites, where available, or acquired via telephone communication. It should be noted that locating appropriate participants was often difficult due to the misinterpretation of TSM&O objectives, the unfamiliarity of the term, or the organizational structure of the DOTs. Information requested in the survey is provided in Appendix F.

Of the fifty states queried, 36, or 72%, responded to the survey, as shown in Figure 6.1. All survey responses are summarized in Tables G.1 through G.7 in Appendix G. Missing question responses were marked as *No Answer*.

6.1 Part I Survey Results

Part I of the questionnaire explored the current state-of-the-practice of TSM&O in the agency's project development process. Questions ranging from organizational structure, TSM&O involvement in project phases, and challenges with TSM&O implementation were asked. The Capability Maturity Model (CMM) level that the agency is currently operating in was also requested. Subsequent follow-up calls were conducted with participants as needed to clarify survey responses and/or to further explore specific responses.

6.1.1 Agency Divisions

Survey participants were asked to select whether their agency contained a TSM&O and ITS division, either division, or neither division. All 36 responding State DOTs replied to this question. Results, listed in Table G.1 and illustrated in Figure 6.1, reveal that the organizational structure varies considerably among the agencies.

The distribution of responses shown in Figure 6.2 highlights the variation in organizational structure. While many states have implemented TSM&O strategies to some degree, just over 39% (14 States) of responding DOTs stated that their agency has a TSM&O division. Additionally, five of the participating DOTs (14%) with TSM&O divisions also contain ITS divisions (Colorado, Iowa, Minnesota, New Hampshire, and New Jersey), as shown in Figure 6.2.

The majority of TSM&O programs have been developed within the last five years. Washington State, Utah, and Virginia DOT are the exception with TSM&O programs established as early as in 1995, 1999, and 2006, respectively. While most of the TSM&O divisions operate as a section of the Traffic Operations division, several DOTs have established TSM&O divisions within their organizational structure. However, not all agencies use the term "TSM&O". Florida DOT has recently renamed their ITS division to a TSM&O division, following the development of the *Florida TSM&O Strategic Plan* in 2013 (FDOT, 2013c). It is anticipated that Washington State

6.1.2 Project Development Process

Survey participants were asked several questions pertaining to TSM&O practices in the project development process in their agency. Thirty-two (32) State DOTs responded to these questions, summarized in Table G.2. When asked if TSM&O staff get involved in the development process for roadway projects, 50% answered *Yes*. However, when asked whether TSM&O staff are involved in the review process of potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase, nearly 41% indicated *No*, compared to 31% of the responding 32 DOTs that indicated that TSM&O staff are included in the review process. Figure 6.3 summarizes the question results. Several DOTs (13%) stated that their agency is either in the beginning stages of TSM&O involvement in the project development process, or that the participation of TSM&O staff is project specific. These responses were categorized as “Other”, as shown in Figure 6.3. More details can be found in Table G.2 of Appendix G.

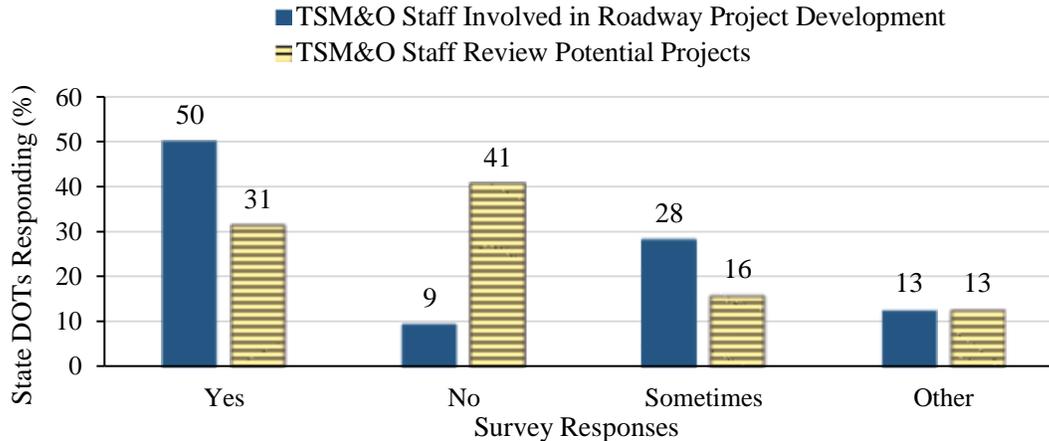


Figure 6.3: TSM&O Staff Involvement in Project Development

Based on a typical project development process consisting of a Planning phase, Design phase, Construction phase, and Operations phase, participants were asked to select all phases in which TSM&O staff get involved. Surprisingly, nearly 68%, or 21 of the 31 responding DOTs, stated that TSM&O staff get involved in the project development process as early as the planning phase, with 52% (16 states) involved in all phases, as shown in Figure 6.4. Fewer than 13%, or 4 states, reported the design phase as their initial involvement.

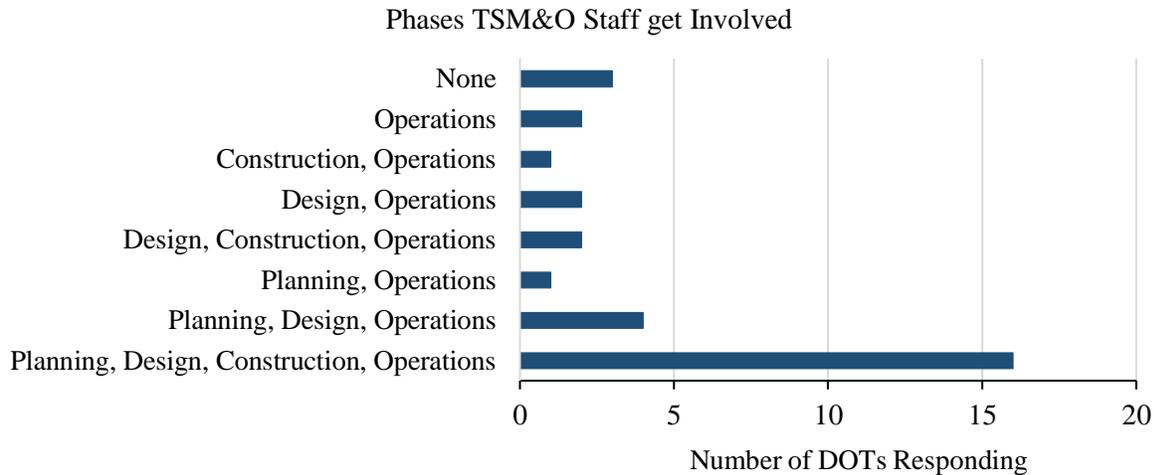


Figure 6.4: Project Development Phase Involvement

6.1.3 Design Process Guidelines

State DOTs were asked how much TSM&O is covered in existing design process guidelines, such as current planning guidelines and design manuals. Participants were asked to select the appropriate level from the following options: A great deal, A lot, A moderate amount, A little, and None. Of the 32 states that responded to this question, fewer than seven percent (6.3%, or 2 states – Delaware and New Jersey) expressed that TSM&O is covered a great deal in the agencies design guidelines, as shown in Figure 6.5. The majority of states (37.5%) indicated that TSM&O is covered a little in their current guidelines, while nearly 22% of the responding agencies do not include TSM&O activities in their project development documents.

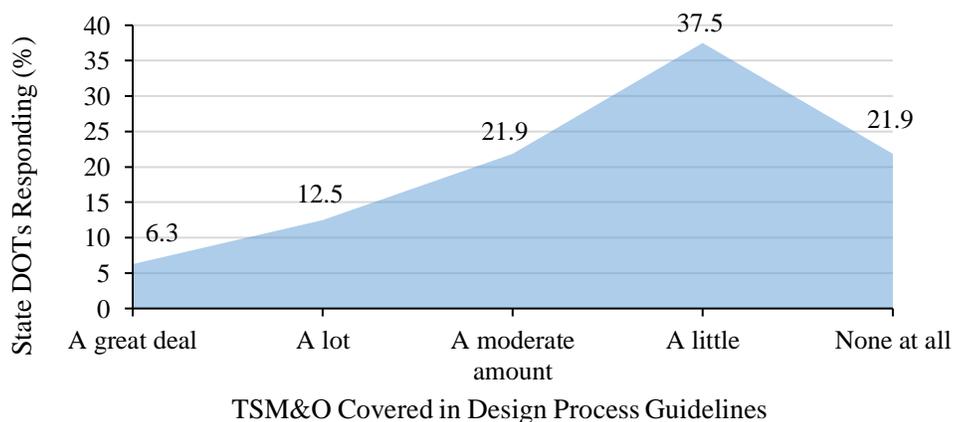


Figure 6.5: TSM&O in Project Development Guidelines

Survey participants were also asked if their agency possessed guidelines stating how TSM&O should be incorporated in the project development process prior to Operations by selecting one of the following options: Yes, No, Not sure, or Other (comment area). As shown in Table 6.1, 53% of the responding 32 DOTs stated that their agencies currently do not have guidelines for including TSM&O in project development prior to Operations. On the other hand, 28% (9 states) currently do have guidelines that include TSM&O. Five states, or 16%, stating in the comment section provided for the “Other” option, that such guidelines are in the developmental stage.

Table 6.1: Agency Guidelines for TSM&O Prior to Operations

Response	Number	%
Yes	9	28
No	17	53
Not Sure	1	3
*Other	5	16
Total	32	100

* In development, per comments

6.1.4 Implementation Challenges

A variety of challenges were expressed, in the form of a comment field, regarding the implementation of TSM&O in the project development process. Based on responses from 29 State DOTs, the results were compiled into eight categories, as shown in Table 6.2.

The greatest challenge in implementing TSM&O in the project development process was that of the culture in the agencies. Nearly 62% of survey participants stated a lack of awareness and general understanding of TSM&O presented a challenge in their agency. Since TSM&O is a fairly new method of managing existing roadway operations, some DOTs have yet to explore the concept. Budgetary and integration issues were also mentioned, consisting of 28% and 24% of the responses, respectively. The categorized responses from each DOT are listed in Table G.4 of Appendix G.

Table 6.2: TSM&O Implementation Challenges

Challenge	No. of Responses	Percentage of Responding DOTs (%) *
Business Process	2	7
Culture/Awareness/Understanding	18	62
Integration	7	24
Workforce	4	14

* 29 DOTs responding

Table 6.2: TSM&O Implementation Challenges (continued)

Challenge	No. of Responses	Percentage of Responding DOTs (%) *
Budgetary	8	28
Consideration	6	21
Coordination	5	17
Guidelines	3	10

* 29 DOTs responding

6.1.5 Capability Maturity Model (CMM)

A series of questions were asked of participants concerning the Capability Maturity Model (CMM), a self-assessment management tool to assist agencies in determining the current state and future areas of improvement of TSM&O within the agency (Gregory & Irwin, 2014). The first of seven questions asked whether the agency utilized the CMM framework to help improve the effectiveness of TSM&O activities. As shown in Table 6.3, four options were available for selection – Yes, No, Not sure, and Other (comment field). With 33 DOTs responding, 16 DOTs (49%) indicated that their agencies do reference the CMM to assess the state of TSM&O in the agency, while 36% (12 states) do not currently use the CMM. Five DOTs, or 15%, stated that they have only attended CMM workshops or that the agency is in the beginning stages of using the CMM. Complete responses are shown in Table G.5 in Appendix G.

Table 6.3: Agency Use of CMM to Measure TSM&O Activities

Response	Number	%
Yes	16	49
No	12	36
Not sure	0	0
Other*	5	15
Total	33	100

* Beginning stages, per comments

The six remaining questions concerning the CMM asked participants to indicate the agency's current Level (1-4) for the six model dimensions: Business Process, Systems & Technology, Performance Measurement, Culture, Organization/Workforce, and Collaboration. Responses are summarized in Tables G.5 through G.7 in Appendix G. An overview of responses, illustrated in Figure 6.6, shows that over half of the agencies are in Level 1 or Level 2 in all six of the modal dimensions, revealing that TSM&O integration into agency practices is still in its infancy in many states.

Over 39% of the responding 33 DOTs consider their agency to be in Level 1 of the CMM Culture dimension, indicating that the value of TSM&O is not widely understood beyond the TSM&O champions. Few states (6%, or 2 states) are currently operating in a Culture Level 4 with an agency commitment to TSM&O strategies. Culture level responses are mapped in Figure 6.7 and listed in Table G.6 of Appendix G.

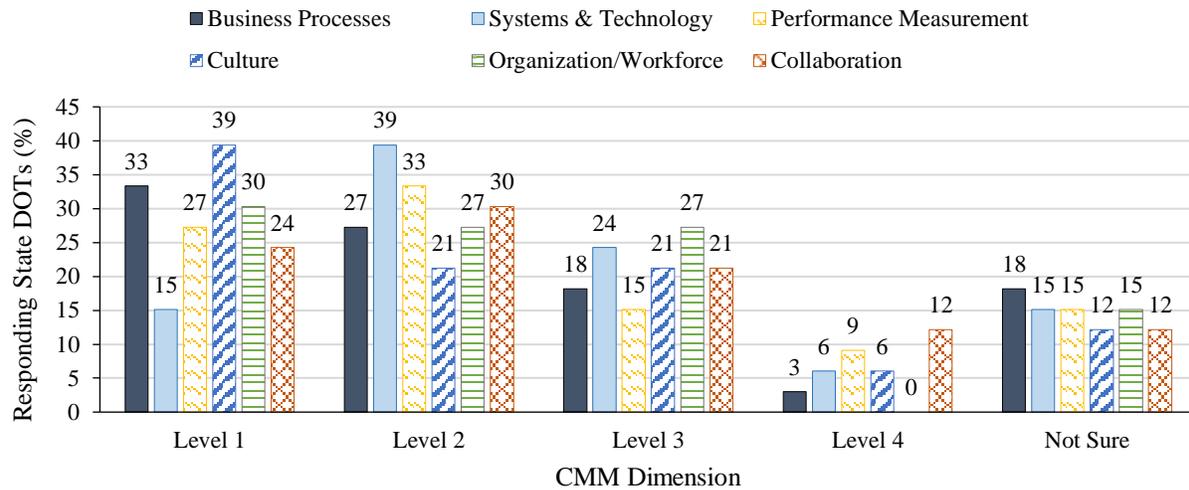


Figure 6.6: DOT Levels in the Capability Maturity Model (CMM)

Responses reveal that 33% of responding DOTs consider the agency to also be in Level 1 of the CMM Business Processes dimension where the majority of processes related to TSM&O are ad hoc and unintegrated. Delaware is the only State DOT that responded at a Level 4. CMM Business processes level responses are mapped in Figure 6.8 and listed in Table G.5 of Appendix G.

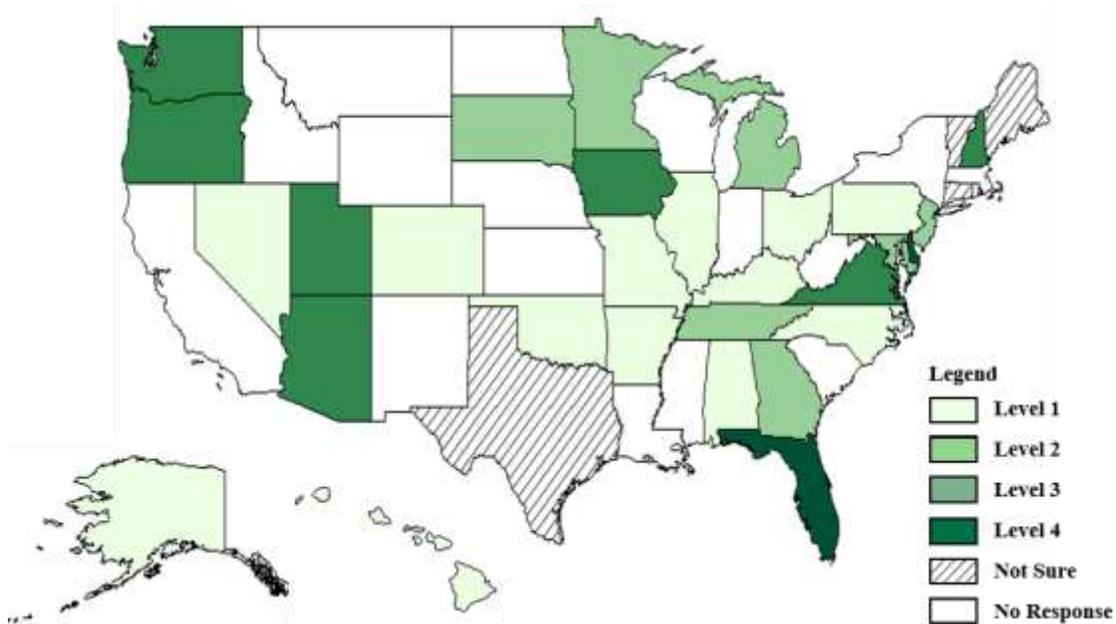


Figure 6.7: CMM Culture Dimension Levels for State DOTs

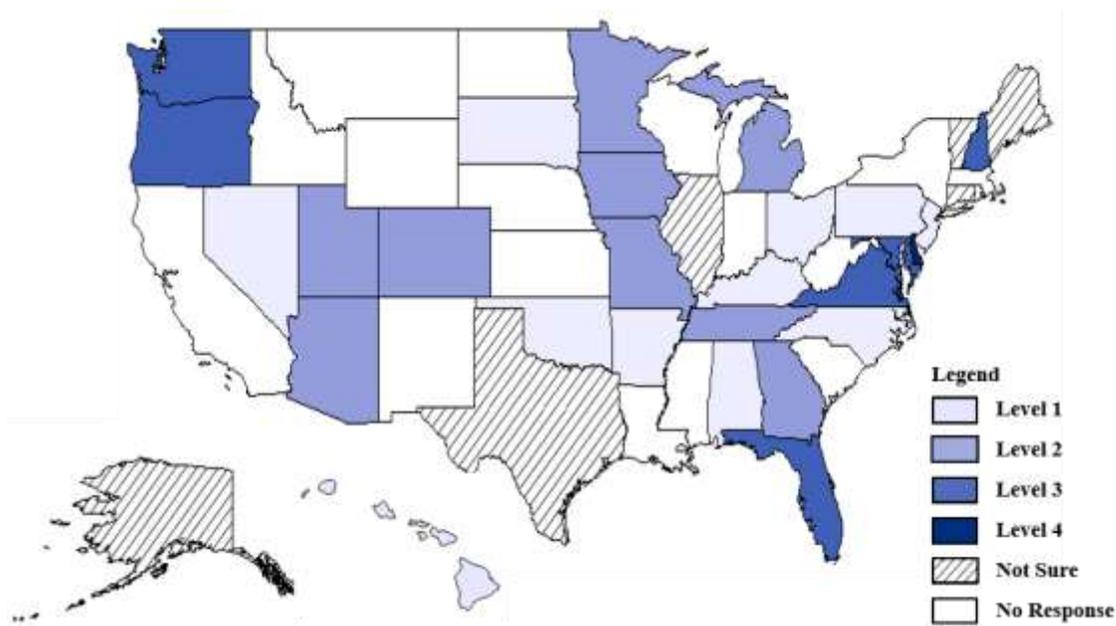


Figure 6.8: CMM Business Processes Dimension for State DOTs

6.1.6 Project Development Best Practices

Over the past decade, State DOTs agencies have realized that unique solutions are needed to address congestion on the nation’s roadways. To improve mobility and safety, TSM&O strategies have been employed for a number of years to better serve the motoring public. While

each state utilizes TSM&O strategies to some degree, several DOTs are moving forward with integrating TSM&O practices throughout the project development process. Other States DOTs have found efficient ways to implement TSM&O activities within the agency's organizational structure. The following examples highlight the wide-ranging initiatives being practiced today.

6.1.6.1 Colorado

In 2014, Colorado Department of Transportation (CDOT) established a TSM&O division that “emphasizes and places a priority” on systematic statewide operations (CDOT, 2016). In an effort to mainstream TSM&O, a TSM&O Evaluation consisting of a safety assessment, an operations assessment, and an ITS assessment is now required for all projects with a Design Scoping Review occurring on or after February 1, 2016 (CDOT, 2016).

6.1.6.2 Delaware

DelDOT has language in their *Project Development Manual* requiring a combination of Transportation Systems Management (TSM) initiatives be considered during the alternative analysis for the majority of projects (DelDOT, 2015).

6.1.6.3 Florida

In recent years, FDOT has added TSM&O evaluation requirements to the alternative analysis process outlined in the *Project Development and Environment (PD&E) Manual* (FDOT, 2009). PD&E procedures also require that modal considerations must be explored in studies related to major urban corridors (FDOT, 2009).

6.1.6.4 Georgia

Georgia Department of Transportation (GDOT) implements TSM&O strategies through their ITS Division for projects containing ITS technologies. GDOT's *ITS Strategic Deployment Plan* calls for ITS device deployments to be included in the planning phase of other larger roadway projects to minimize multiple construction efforts along Georgia freeways (Boodhoo, 2008).

6.1.6.5 Maryland

Maryland Department of Transportation State Highway Administration (MDOT-SHA) has taken the lead in considering TSM&O in the planning phase of the project development process for their 5-, 10-, and 20-year LRTPs, which allows for possible funding. Since capacity expansion is limited, corridor management has been the key focus area for the Baltimore-Washington region, with an emphasis on improving system efficiency and reliability, rather than on reducing congestion in one of the nation's most heavily congested areas. Although their TSM&O program has yet to be formally adopted, TSM&O alternatives have been evaluated alongside no-build and build alternatives using a Benefit-Cost (B/C) analysis on roadway improvement projects for a number of years. MDOT-SHA has initiated a comprehensive and coordinated approach to

TSM&O activities using a collaborative effort among the Office of Planning, Office of Highway Development, Office of Traffic and Safety, Office of Maintenance, and the Office of CHART (Coordinated Highways Action Response Team) & ITS in lieu of establishing a TSM&O Division.

6.1.6.6 New Hampshire

New Hampshire Department of Transportation (NHDOT) is moving forward with statewide TSM&O initiatives. Published in 2014, the *TSM&O 5-year Strategic Plan* outlines specific initiatives that should be considered during project development to achieve the states' ITS Program goals (NHDOT, 2014). Recognizing that ITS needs may differ throughout the State, two ITS regions were established – the Southern/Urban region and the Northern/Rural region. Future ITS deployment strategies are determined by the ITS region. A mainstreaming approach of incorporating ITS components in the design phase of a roadway project is utilized in the Northern region, while the stand-alone project method is primarily used in the Southern region (NHDOT, 2014).

6.1.6.7 New Jersey

New Jersey Department of Transportation (NJDOT) has not only established a Transportation Systems Management (TSM) division within the agency's organizational structure that concentrates on the flow and routing of traffic along the state's highway system, but also has recently developed a TSM Procedures Manual (NJDOT, 2015) to provide guidance on the design, installation, operation, and maintenance of NJDOT Intelligent Transportation System (ITS) assets. A key procedural element is the Systems Engineering process for all new or refunctioned ITS deployments. The process considers all phases of the ITS system's lifecycle, and requires the completion of a System Engineering Review Form (SERF) during the concept development phase of all projects (NJDOT, 2015).

6.2 Part II Survey Results

Part II of the questionnaire focused on the project delivery systems, procurement practices, contract management methods, and system development strategies (i.e., models) that are currently being used by the states for their TSM&O and ITS projects. Furthermore, the survey questionnaire also included information on the existing funding sources for TSM&O and ITS projects.

This section focuses on the project delivery systems, procurement practices, contract management methods, and system development strategies (i.e., models) that are currently being used by state DOTs. More specifically, the survey participants provided example project types for the various project delivery systems, procurement practices, and contract management methods. As stated in Chapter 2 of this report, a total of 36 State DOTs responded to the survey. All responses for this part of the questionnaire are summarized in Tables H.1 through H.6 in Appendix H.

For better presentation of survey responses, all the project types provided by the states were categorized into the following broader categories:

- ITS
 - ITS Corridor Deployment Projects
 - ITS Maintenance and Equipment/Devices Projects
 - Interstate Managed Lane Program with Dynamic Tolling
 - Weigh-in-Motion Projects
 - Fiber Network Projects
 - Active Traffic/Safety Management Projects
 - Rural Intersection Conflict Warning System
 - Technology Solutions
- Traffic Engineering and Operations
 - Traffic Signals
 - Travel Demand Management Projects
 - Traffic Capacity and Operations
 - Design, Maintenance and Planning Projects
- Highway/Bridge Construction
 - Traditional Construction Projects
 - Interstate Widening Projects
 - Toll Roads, Expressway Construction Projects
 - Roadway Improvements/3R Projects
 - Bridge Work Projects
- All/Major Projects
 - All/Large Capacity and High Profile Projects
- Others
 - Railway Construction
 - Signing and Pavement Marking
 - Professional Design Services
 - Professional Services
 - Highway Safety
 - Safety Service Patrol
 - Information Technology (IT)
 - Purchase Order Contracts for Equipment
 - Time Restricted Projects
 - Asset Management (e.g., Grass Mowing)
 - Personnel Management
 - Land and Building Improvements Projects

6.2.1 Project Delivery Systems

Project delivery systems are the overall processes by which a project is designed, constructed, and/or maintained. TSM&O/ITS projects benefit from considering more innovative approaches

which could potentially improve the speed and efficiency of the project delivery process. As such, one of the survey questions focused on example project types for the project delivery systems currently being used by the state DOTs. Of the 36 State DOTs that responded to the survey, 24 states provided this information.

Figure 6.9 gives the different project delivery systems that are used by state DOTs for ITS, traffic engineering and operations, highway/bridge construction, and all/major projects. Table 6.4 provides the project delivery systems used by DOTs for projects that are not listed in Figure 6.9.

Design-Bid-Build is the most commonly used project delivery system. Design-Build and Contract Maintenance are also frequently used by the DOTs. Construction Manager at-Risk is the least common delivery system among the options included in the survey. When only ITS and traffic engineering and operations projects are considered, Contract Maintenance and Design-Bid-Build project delivery systems are more common. As expected, the traditional delivery systems, Design-Build and Design-Bid-Build systems, are commonly used for highway and bridge construction projects.

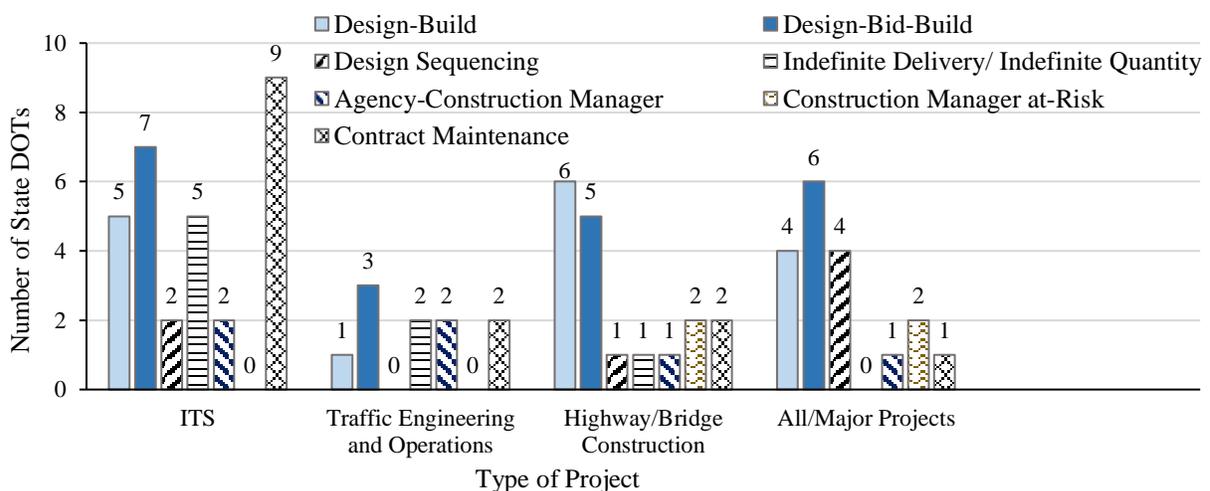


Figure 6.9: Project Delivery Systems Used by State DOTs

Table 6.4: State DOTs Project Delivery Systems for Uncommon Project Types

Type of Project	Project Delivery System
Railway Construction	Contract Maintenance
Signing and Pavement Marking	Agency-Construction Manager, Contract Maintenance
Professional Design Services	Contract Maintenance*

* Two DOTs mentioned that they use Contract Maintenance delivery system for professional design services.

Table 6.4: State DOTs Project Delivery Systems for Uncommon Project Types (continued)

Type of Project	Project Delivery System
Highway Safety	Design-Bid-Build
Information Technology	Indefinite Delivery/ Indefinite Quantity
Purchase Order Contracts for Equipment	Indefinite Delivery/ Indefinite Quantity
Time Restricted Projects	Construction Manager at-Risk
Asset Management (e.g., Grass Mowing)	Contract Maintenance
Personnel Management	Contract Maintenance

Since a Design-Build contract may also include responsibilities such as warranty, maintenance, operations, etc., the following delivery systems are becoming increasingly popular:

- Design-Build-Warranty
- Design-Build-Maintain
- Design-Build-Operate
- Design-Build-Operate-Maintain

Over 50% of the responding states (i.e., 16 of 31) stated that they use Design-Build delivery system. On the other hand, 20% of the responding states stated that they do not use Design-Build delivery system. Nine of the responding states are not sure of which Design-Build system used by the agency. Survey responses are listed in Table H.2 of Appendix H.

As can be observed from Figure 6.10, among the different types of Design-Build delivery systems, the Design-Build-Warranty system where a single contract team designs, constructs, and warrants specified highway components over a prescribed time period is the most common delivery system, of the 16 states that responded. Note that the remaining three Design-Build systems are equally popular.

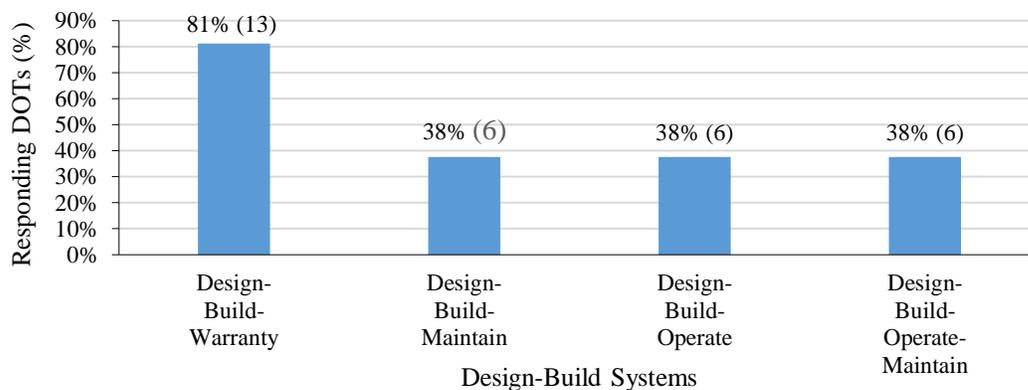


Figure 6.10: Design-Build Delivery Systems Used by State DOTs

6.2.2 Procurement Practices

Procurement practices are the overall procedures by which a project is to be evaluated for the selection of designers, contractors, and various consultants. Of the 36 total responding state DOTs, 16 provided example project types for the following procurement practices:

- Cost-Plus-Time Bidding (A+B)
- Multi-Parameter Bidding (A+B+C)
- Lump Sum Bidding
- Alternate Design
- Alternate Bid
- Additive Alternates
- Best-Value Procurement
- Bid Averaging

Table 6.5 provides the procurement practices currently being used for different types of projects. Note that the projects are divided into four broad categories: all/major projects, ITS, traffic engineering and operations, highway/bridge construction, and others. The ‘others’ category includes safety service patrol, professional services, IT, and land and building improvement projects. The traditional highway/bridge construction projects are often procured using Alternative Design and Alternate Bid methods. On the other hand, the ITS and traffic engineering and operations projects are procured using several different practices. Survey responses are listed in Table H.3 of Appendix H.

Table 6.5: Procurement Practices Used by State DOTs

Type of Projects	Procurement Practices
All/Major Projects	<ul style="list-style-type: none"> • Cost-Plus-Time Bidding (A+B) (3) • Alternate Design
ITS	<ul style="list-style-type: none"> • Cost-Plus-Time Bidding (A+B) • Additive Alternates • Best-Value Procurement (4)
Traffic Engineering and Operations	<ul style="list-style-type: none"> • Cost-Plus-Time Bidding (A+B) • Multi-Parameter Bidding (A+B+C) • Lump Sum Bidding • Best-Value Procurement
Highway/Bridge Construction	<ul style="list-style-type: none"> • Alternate Design (2) • Alternate Bid
Safety Service Patrol	<ul style="list-style-type: none"> • Best-Value Procurement
Professional Services	<ul style="list-style-type: none"> • Cost-Plus-Time Bidding (A+B) • Best-Value Procurement
Information Technology (IT)	<ul style="list-style-type: none"> • Lump Sum Bidding
Land and Building Improvements Projects	<ul style="list-style-type: none"> • Additive Alternates

Note: The total number of states, when more than one state listed the specific type of project, is shown in parentheses. For example, three states mentioned that they use Cost-Plus-Time bidding (A+B) procurement method for all/major projects in their states.

6.2.3 Contract Management Methods

Contract management methods are the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. Of the 36 responding state DOTs, 14 provided example project types for the following contract management methods:

- Incentives/Disincentives (I/D) Provisions for Early Completion
- Lane Rental
- Flexible Notice to Proceed Dates
- Warranties
- Liquidated Savings
- Active Management Payment Mechanism (AMPM)
- No Excuse Incentives

Figure 6.11 shows the contract management methods that are used by the states for highway/bridge construction, and all/major projects. Note that all the projects were broadly categorized into these two types. As can be observed from Figure 6.11, Incentives/Disincentives (I/D) provisions for early completion is the most common contract management method used by the agencies. The other methods are used very rarely. Note that none of the states use Warranties or Active Management Payment Mechanism (AMPM) contract management methods. Survey responses are listed in Table H.4 of Appendix H.

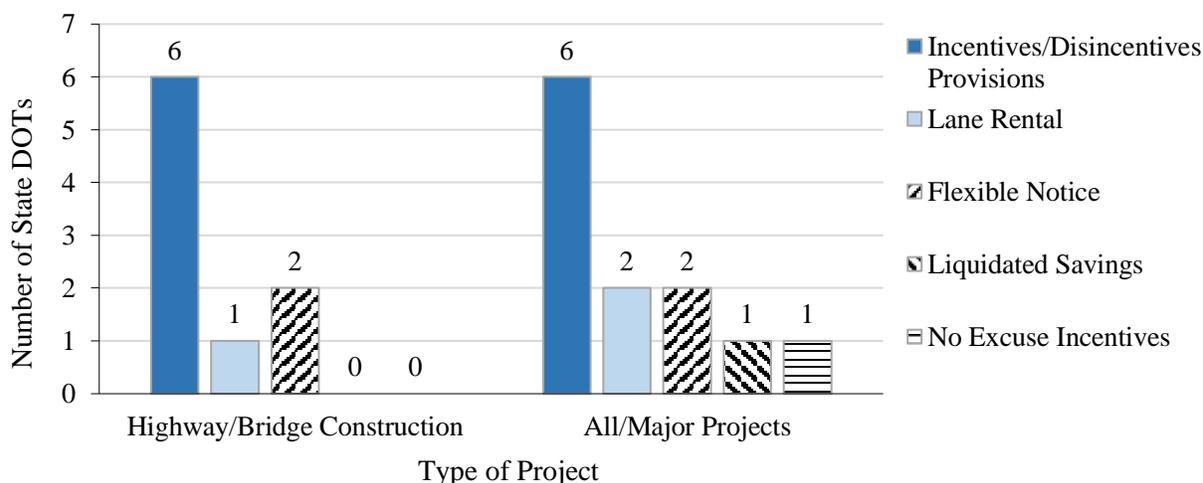


Figure 6.11: Contract Management Methods Used by State DOTs

6.2.4 Funding Sources for TSM&O Projects

A total of 28 states provided information about funding sources for their TSM&O projects. The states selected all the applicable funding sources from the following options:

- Congestion Mitigation and Air Quality Improvement (CMAQ) Program
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- National Highway Performance Program (NHPP)
- Transportation Investment Generating Economic Recovery (TIGER)
- Highway User Revenue Fund
- Local taxes
- Unified Planning Work Program (UPWP)
- Public-private partnership

Figure 6.12 summarizes the results on funding sources for TSM&O projects. All the responding states except Maine, New Jersey, and Vermont fund their TSM&O projects from more than one funding avenue. Virginia funds TSM&O projects using all the listed funding sources. As shown in Figure 6.12, a majority of states fund TSM&O projects using STP (75%) and CMAQ (71%) programs. On the other hand, very few agencies (7%) have the Unified Planning Work Program (UPWP). Note that Figure 6.12 includes an additional category, ‘State Funds’, since four state DOTs stated that they use state funds for TSM&O projects. Survey responses are listed in Table H.5 of Appendix H.

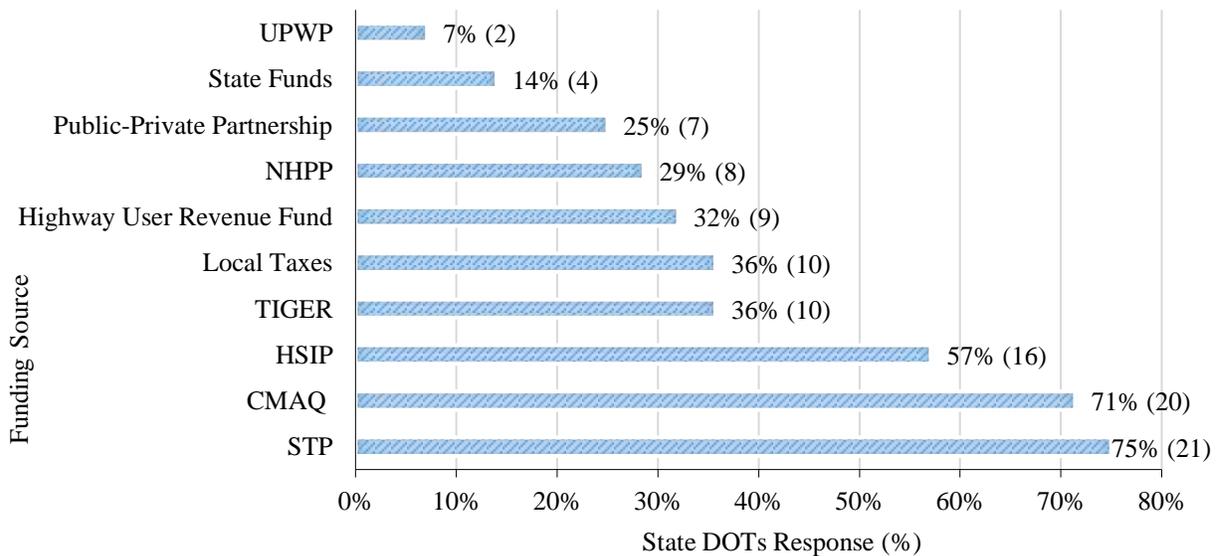


Figure 6.12: State DOTs Funding Sources for TSM&O Projects

Of the 30 responding states, 12 states (40%) combine set-aside dedicated funding with the ability for TSM&O projects to compete for other funding. Seven states (23.3%) set aside dedicated

funding for TSM&O projects, while 5 states (16.7%) allow TSM&O projects to compete with other types of projects for funding.

Alabama and Delaware mentioned that they follow other strategies. Regional Traffic Management Center (RTMC) and service patrol operations in Alabama are funded annually within the routine maintenance budget. Delaware reviews all projects for the TSM&O costs where warranted. Michigan sets aside funding for ITS projects, and also blends in ITS strategies with capital improvement projects. In North Carolina, new devices compete with other projects for TSM&O funding with state funds. In Pennsylvania, projects are funded by planning partners as well as state dollars in their statewide budgets. Survey responses are listed in Table H.6 of Appendix H.

6.2.5 System Development Processes

Waterfall, Incremental Build, Agile, and Spiral Models are the four most commonly used system development strategies (i.e., models). As shown in Figure 6.13, 11 of the 20 states that responded use the Waterfall development model for TSM&O/ITS projects. Incremental Build and Agile models are used by six and four states, respectively. Note that none of the responding states stated that they use Spiral model for TSM&O and ITS projects.

Virginia uses milestones with sprints for Advanced Traffic Management Systems (ATMS) projects and Waterfall for other projects. Iowa uses a different system development strategy, and two other states, Colorado and Pennsylvania, are unsure about the system development model they use. Survey responses are listed in Table H.6 of Appendix H.

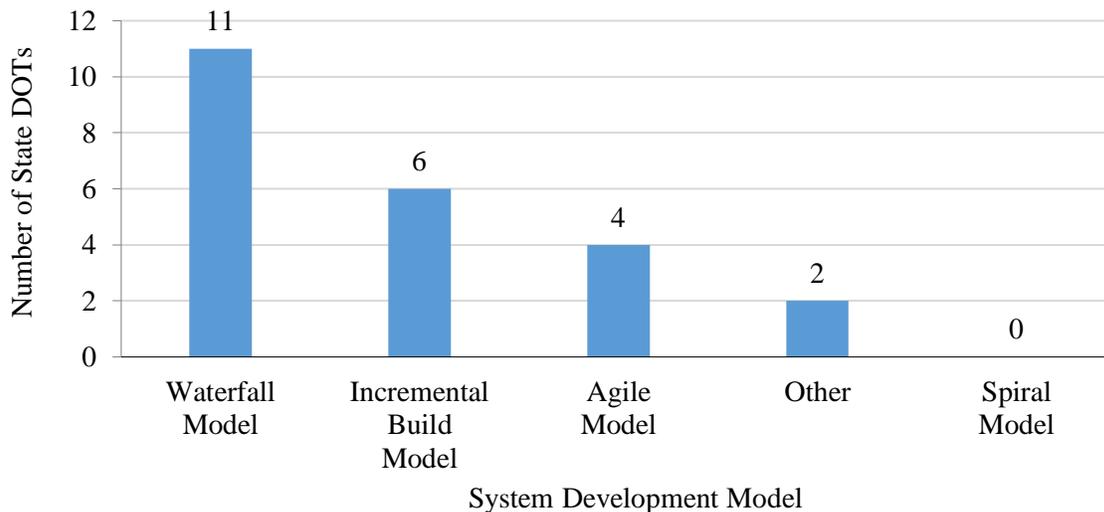


Figure 6.13: System Development Strategies Used by State DOTs

Table 6.6 provides the system development models used by state DOTs for highway/bridge construction projects, ITS and traffic engineering and operations projects, and all/major projects. As can be observed from Table 6.6, for construction projects, Incremental Build model is most frequently used, immediately followed by the Waterfall model. For ITS and traffic engineering and operations projects, Waterfall model is the most frequently used model. The Agile and Incremental Build models are also frequently used by the agencies. For all/major projects, the Waterfall model is the most frequently used model.

Table 6.6: System Development Strategies Used by State DOTs

Strategy	Design-Build	Design-Bid-Build	Design Sequencing	(ID/IQ)	Agency-Const. Manager	Const. Manager at-Risk	Contract Maintenance	Total
Highway/Bridge Construction Projects								
Waterfall	2	1	0	0	0	2	0	5
Incremental Build	2	1	0	1	1	0	1	6
Agile	1	0	0	0	0	2	0	3
Total	5	2	0	1	1	4	1	14
ITS and Traffic Engineering and Operations Projects								
Waterfall	3	5	2	2	1	0	3	16
Incremental Build	2	1	1	1	1	0	2	8
Agile	1	2	1	2	1	0	2	9
Total	6	8	4	5	3	0	7	33
All/Major Projects								
Waterfall	2	4	3	0	1	1	1	12
Incremental Build	0	1	0	0	0	0	0	1
Agile	1	2	1	0	0	0	0	4
Total	3	7	4	0	1	1	1	17

6.2.6 Key Findings

The following is a list of key findings from the state-of-the-practice survey of State DOTs:

- Design-Bid-Build is the most commonly used project delivery system.
- Construction Manager at-Risk is the least common delivery system among those included in the survey.
- Contract Maintenance and Design-Bid-Build project delivery systems are more common for ITS and traffic engineering and operations projects.
- The traditional delivery systems, Design-Build and Design-Bid-Build systems, are commonly used for highway and bridge construction projects.

- Among the different types of Design-Build delivery systems, the Design-Build-Warranty system is the most common delivery system.
- The traditional highway/bridge construction projects are often procured using Alternative Design and Alternate Bid methods.
- The ITS and traffic engineering and operations projects are procured using several different practices.
- Incentives/Disincentives (I/D) provisions for early completion is the most common contract management method.
- A majority of states fund TSM&O projects using STP (75%) and CMAQ (71%) programs.
- Waterfall development model is commonly used for TSM&O/ITS projects.
- For construction projects, Incremental Build model is most frequently used, immediately followed by the Waterfall model.
- For ITS and traffic engineering and operations projects, Waterfall model is the most frequently used model.
- For all/major projects, Waterfall model is the most frequently used model.

6.3 Chapter Summary and Discussion

To determine the extent to which TSM&O is considered in the project development process outside of Florida, TSM&O staff at State DOTs were contacted to provide their current practices and how TSM&O is being incorporated. A two-part online survey questionnaire was administered to State DOT staff in each state within the U.S. Part I of the questionnaire explored the current state-of-the-practice of TSM&O in the agency's project development process, while Part II focused on the project delivery systems, procurement practices, contract management methods, and system development strategies (i.e., models) that are currently being used by the states for their TSM&O and ITS projects.

Many states are moving forward with TSM&O initiatives to meet their mobility needs and, in some cases, developing a TSM&O division to serve as a focal point to manage their multimodal networks. However, the organizational structure varies considerably among the DOTs nationwide, and some agencies prefer to address TSM&O through interoffice collaboration efforts.

Although a few TSM&O strategies, such as traveler information systems and HOV lanes, have been employed by many states for a number of years, State DOTs are recognizing that to provide reliable, safe travel to the motoring public, alternative solutions to traditional roadway expansion measures are needed, especially in the current fiscal climate of limited transportation funding. However, survey responses indicate that while the mainstreaming of TSM&O into agency project development processes is increasing nationwide, the majority of State DOTs are still in the early stages of implementation. Over half of the agencies responded at being in Level 1 or Level 2 in all six of the CMM modal dimensions.

Survey responses reveal that the greatest challenge related to TSM&O implementation among the DOTs is that of the culture within the agency. Lack of awareness or understanding of the TSM&O concept affects a number of aspects required for a successful program, such as necessary funding, project alternatives consideration, and process and procedure integration – all of which were expressed as leading challenges of TSM&O implementation by survey participants. Consequently, coverage of TSM&O in existing design or planning guidelines is lacking with over half of the responding states indicating that TSM&O is addressed very little or not at all in their project development guidelines.

A large percentage of responding states reported getting involved in the project development process as early as the planning phase. However, it is expected that the majority of these responses were referring to the planning phase of ad hoc operations projects. For states with little to no clear procedural objectives, it is unclear as to degree that that TSM&O is considered prior to the operations phase.

A few states are more advanced in their TSM&O directives. Through this survey, several states have been identified as successfully incorporating TSM&O early in the project development process. Best practices from the states that have established process procedures and guidelines for TSM&O may serve as potential recommendations for FDOT process improvements.

7 – EXISTING DEVELOPMENT PROCESS

This chapter focuses on the current project development process for TSM&O projects in Florida. A survey was administered to obtain information about the current project development process used in TSM&O, ITS, and Advanced Traffic Management Systems (ATMS) projects conducted at the district and state level within the FDOT. The document is divided into six major sections.

- Section 7.1 focuses on the FDOT project development cycle.
- Section 7.2 discusses the provisions in the Project Development and Environment (PD&E) Manual in the context of TSM&O projects.
- Section 7.3 focuses on the systems engineering approach in the context of TSM&O projects.
- Section 7.4 describes the TSM&O project development process.
- Section 7.5 discusses the survey administered to understand the project development methods used in TSM&O, ITS, and ATMS projects in Florida. The survey results are also presented in this section.
- Section 7.6 provides a brief summary of this research effort.

7.1 FDOT Project Development Cycle

The Florida TSM&O Strategic Plan defines TSM&O as “an integrated program to optimize the performance of existing multimodal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of Florida’s transportation system” (FDOT, 2013c). The Plan identifies opportunities to incorporate TSM&O within all phases (i.e., planning, design, construction, operations, and maintenance) of the project development cycle. This high-level document provides a foundation to understand the need and deployment of TSM&O programs in FDOT projects. Table 7.1 lists the TSM&O outcomes that FDOT desires to achieve from its project development cycle (FDOT, 2013c).

Table 7.1: FDOT Project Development Cycle – TSM&O Outcomes

Project Phase	TSM&O outcomes
Planning	<ul style="list-style-type: none"> • Projects undergo a benefit-cost or net present value assessment. • Operations and management strategies are incorporated into every project. • Projects are selected based on the ability to maximize operations and capacity. • Operations are incorporated into long range plans (Metropolitan Planning Organization (MPO) and Corridor Master Plans). • Data, tools, and performance measures are used to assess operations projects. • Tools and modeling take into account the impact of both operations and capacity projects. • Networks for operations are planned and taken into account in MPO plans. • Formal memoranda of understanding or interagency agreements are in place for operating defined transit, arterial, and freeway systems.
PD&E	<ul style="list-style-type: none"> • All projects consider TSM&O alternatives through an evaluation process.

Table 7.1: FDOT Project Development Cycle – TSM&O Outcomes (continued)

Project Phase	TSM&O outcomes
Design	<ul style="list-style-type: none"> • Operations and management strategies are incorporated into every project.
Operations	<ul style="list-style-type: none"> • Networks are identified, and freeways and arterials are managed in real-time. • Statewide program is defined for ATMS operations and support. • Performance measures are used.
Construction	<ul style="list-style-type: none"> • Real-time traffic management is used during construction maintenance of traffic phases.
Maintenance	<ul style="list-style-type: none"> • Real-time management of traffic is used during maintenance activities. • Sensors are deployed and used to monitor infrastructure condition.

7.2 Project Development and Environment (PD&E) Manual

Part 1, Chapter 4 of the Florida PD&E Manual discusses the project development and delivery process for transportation projects. The process, as shown in Figure 7.1, consists of four phases: planning, PD&E, design, and construction. At the Planning phase, several transportation improvement plans and programs are reviewed to come up with a list of projects that are likely to meet transportation needs. The Efficient Transportation Decision Making (ETDM) Environmental Screening Tool (EST) is then used to identify potential impact of the projects. During the PD&E phase, different alternatives are analyzed, environmental studies are conducted, and technical reports are prepared to obtain Federal and State approvals. The Design phase involves preparing detailed design, final construction plans, specifications, and final cost estimates. Finally, in the Construction phase, the project ends with the construction and delivery of the facility (FDOT, 2017f). Figure 7.1 outlines the project development process described in the current PD&E Manual.

TSM&O projects are performance-based, and consist of not only ITS strategies, but also other reliability and safety strategies, such as hard-shoulder running and signing and marking modifications. However, the majority of TSM&O projects contain ITS technologies, and as a result, are increasingly software-based. These TSM&O/ITS projects often require the collection and analysis of large amounts of data. Therefore, the project development processes for ITS projects could be applicable to the majority of TSM&O projects, requiring minimal tweaking. Also, TSM&O strategies can be a component of a roadway construction project, or a stand-alone project.

Unlike roadway construction projects, stand-alone ITS projects do not have a PD&E phase; preparation of a State Environmental Impact Report (SEIR) or a National Environmental Policy Act (NEPA) document are not required for stand-alone ITS projects. It is therefore evident that the aforementioned project development process presented in the PD&E manual may not be suitable for stand-alone TSM&O projects.

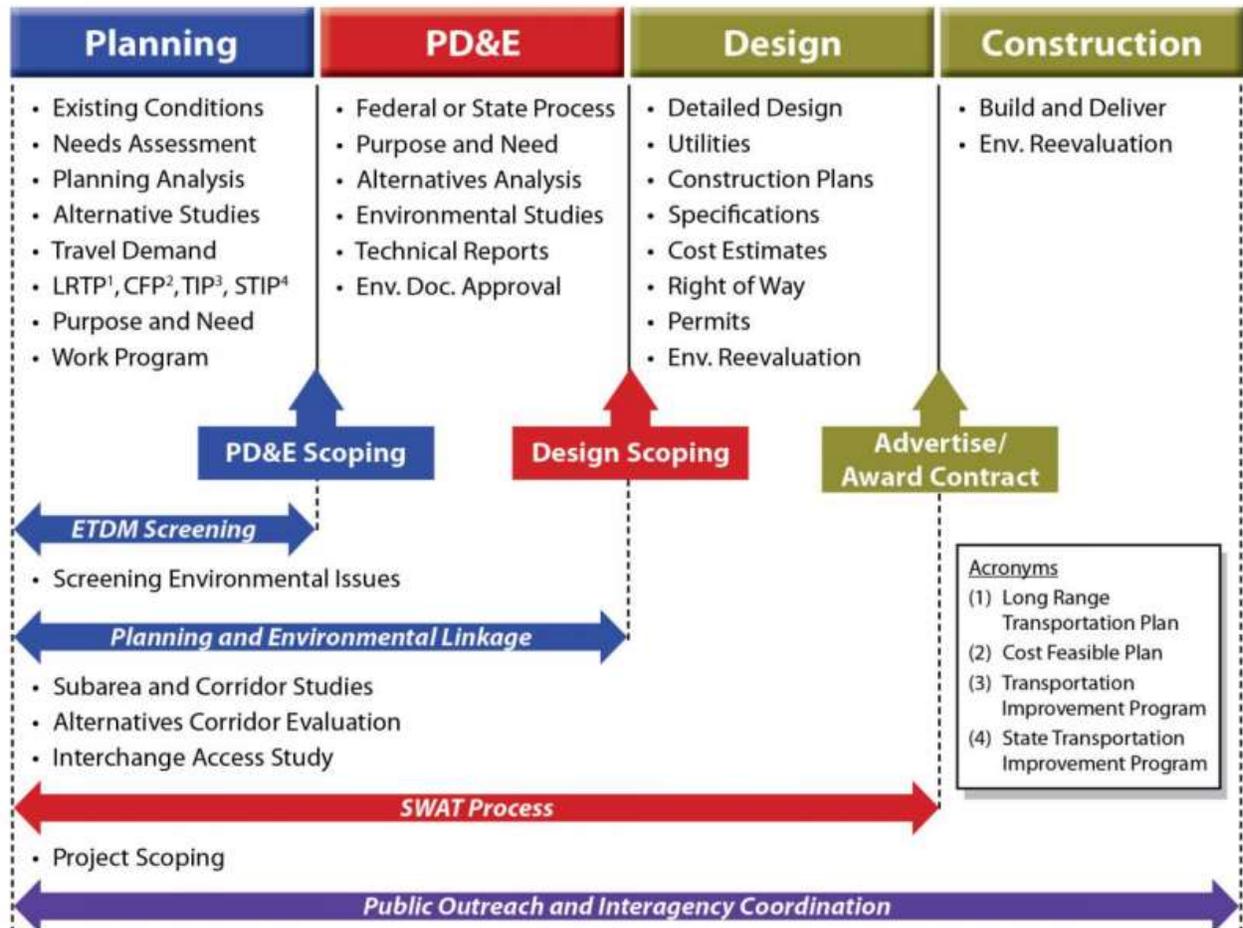


Figure 7.1: Project Development Process in the Florida PD&E Manual
(Source: FDOT, 2017f)

7.2.1 State-Wide Acceleration Transformation (SWAT)

A notable revision to the current version (2017) of the PD&E manual is the addition of State-Wide Acceleration Transformation (SWAT) teams established in each District (FDOT, 2017f). The purpose of the SWAT team is to assist project managers and consultants with scoping and scheduling during the planning and PD&E scoping processes (FDOT, 2017f). Members of the SWAT team include FDOT staff members from multiple disciplines, such as, Intermodal System Development (ISD)/Planning, Design, Environmental office, Production/Scheduling, and the Work Program. Although TSM&O is not specially mentioned, staff from other District offices are invited to participate in the process (FDOT, 2017f).

The SWAT project management approach focuses on speeding up the project delivery process and accelerating pre-construction activities. This approach provides a process for linking planning to PD&E, and PD&E to design. Illustrated in Figure 7.2, the three main components of the SWAT

process consist of the SWAT Planning Meeting, SWAT Strategy Meeting, and the SWAT Kick-off Meeting.

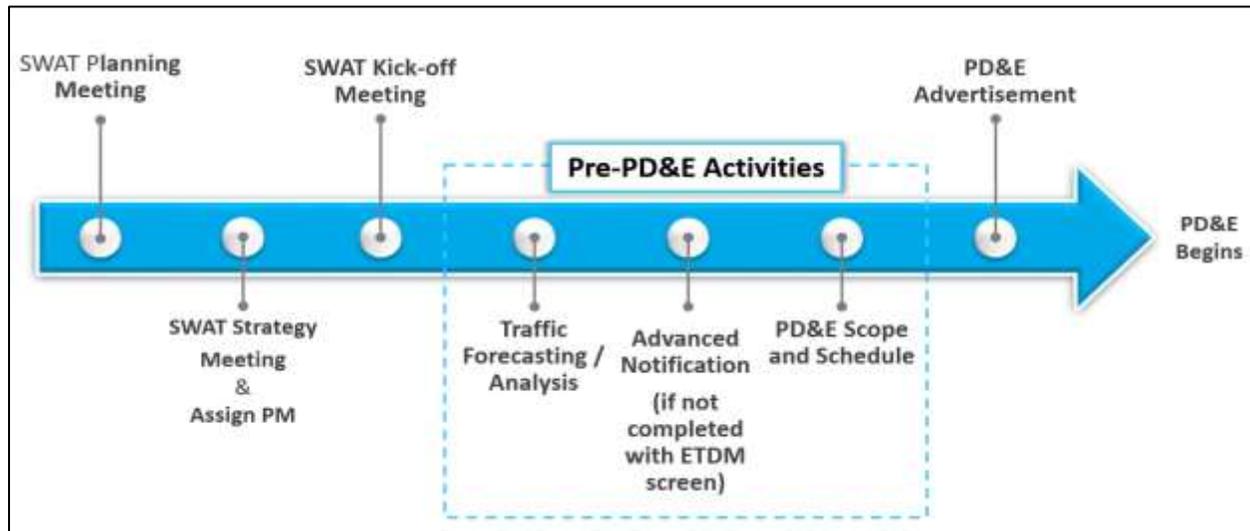


Figure 7.2: SWAT Process Components
(Source: Kirby & Hiers, 2017)

Described by Kirby & Hiers (2017), the SWAT planning meeting should produce:

- List of projects to be programmed as State Funds Only (SFO)
- List of projects to be programmed as Federal funded projects
- Preliminary Environmental Document Class of Action
- Non-Major State Action (NMSA) and Categorical Exclusion (Type 1 CE) projects; no PD&E phase or further SWAT consideration needed
- List of projects for ETDM Programming Screen
- Coordinated list of Advanced Production Potential (APP) Projects

The SWAT strategy meeting will assign a Project Manager, if not already established, and also update the SWAT scoping form information. The meeting will also determine refined project schedules that show the SWAT kick-off meeting, ETDM screening, advanced planning/corridor studies (if needed), PD&E advertisement, and a conceptual project schedule. Described by Kirby & Hiers (2017), the SWAT kick-off meeting should produce:

- List of activities to be advanced prior to PD&E
- Detailed project schedule
- Preliminary assessment of risks and constraints
- Project delivery method
- Procurement approach
- Project Management structure

- Draft scope of services

7.3 Systems Engineering Approach

Title 23, Part 940 of Code of Federal Regulations (23 CFR § 940.11) requires that “all ITS projects funded with highway trust funds shall be based on a systems engineering analysis”. Systems engineering is “*an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem*” (Honour, 2004). Systems engineering provides a means to address several critical issues encountered while developing a project. Table 7.2 lists some of the critical issues and how these issues could be addressed using a systems engineering approach (National ITS Architecture Team, 2007).

Systems engineering is a highly adaptable, resilient, and systematic approach which can be applied to the wide range of TSM&O/ITS projects. In general, systems engineering follows the below principles:

- Realistic understanding of the project goal.
- Input from stakeholders and collaboration among different groups.
- Clear definition of the problem prior to implementing the solution.
- Application of recent and advanced technological innovations by selecting them just prior to implementation.
- Decomposition of a system into subsystems and then of the subsystems into hardware and software components.
- Traceability between project steps to ensure connectivity between the user needs and the end product.

Table 7.2: Abilities of Systems Engineering Approach

Issue	Solution using Systems Engineering Approach
High expectations set at the beginning of a project might not necessarily reflect proper knowledge of existing or new technology and funding constraints, which may ultimately lead to project failure.	The systems engineering approach focuses on early establishment of a realistic project goal, thereby balances between natural expectations and practical constraints.
Limited experience of the project team undertaking high-technology-related ITS project poses significant uncertainty in project cost estimates as well as project scheduling.	The systems engineering approach reduces the risk of cost overruns and impractical project schedule by setting well-defined requirements early in the project.

Table 7.2: Abilities of Systems Engineering Approach (continued)

Issue	Solution using Systems Engineering Approach
The traditional procurement methods are not well suited for ITS projects that require iterative and collaborative processes between the design and implementation phases for their successes.	The systems engineering process is designed to obtain immediate feedback from users, thus allowing for necessary repetition of a design or implementation step.
Any changes to project requirements at the later stage of a project or fixing an error after the project closeout is expensive. The cost of fixing an error might rise up to 100 times when a significant amount of time is elapsed to detect the correction as compared to that when the correction is detected immediately (i.e., time elapsed is minimal).	The systems engineering process performs verification and validation of each intermediate step of design and implementation phases, thereby maximizing the chances of early detection of defects.

Two of the most popular systems engineering project development models for ITS projects are the *Waterfall* and *Vee* models. The following subsections briefly discuss these two models in detail.

7.3.1 Waterfall Model

The Waterfall model is a linear sequential project development process that moves downward through the phases of requirements analysis, design, code, integration, test or verification, and deployment, as shown in Figure 7.3. The underlying idea of the Waterfall model is that each phase must be fully completed and approved prior to proceeding to the next phase (Fox & van der Walddt, 2008).

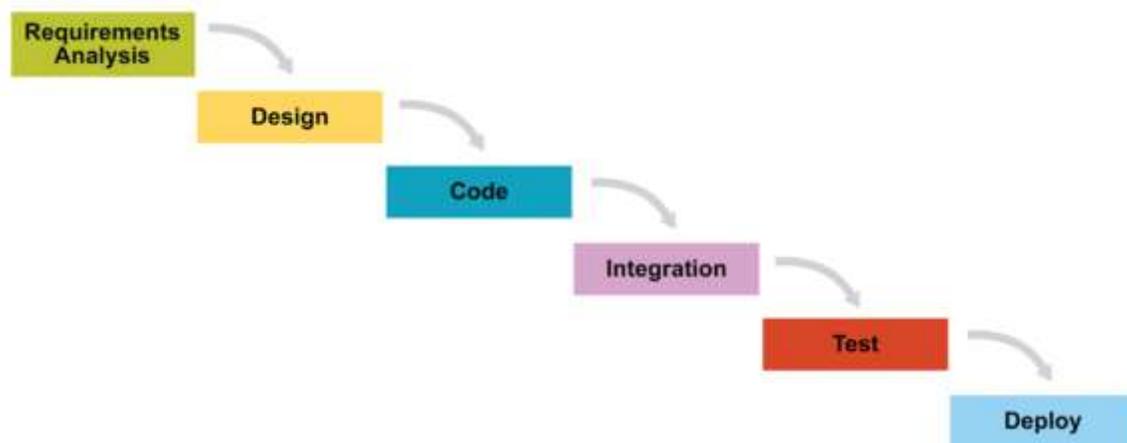


Figure 7.3: Waterfall Model
(Source: James & Walter, 2010)

The Waterfall model is suitable for low-risk ITS projects. The attributes that define a low-risk project include (Vollmer, 2015):

- The project scope pertains to single jurisdiction and single mode (e.g., highway, transit, rail).
- No software development is required. Commercial Off-The-Shelf (COTS) or existing software programs can be used to implement the project.
- The required hardware and communications technology are proven and verified.
- No new interfaces are required.
- System requirements are well defined and fully documented from the beginning of the project.
- Operating procedures are well defined and fully documented.
- No technologies are near to end-of-service life and likely to change.

However, the waterfall model poses high risk and uncertainty to a project and is susceptible to failure when project requirements are not well-defined at the beginning, or likely to change as the project progresses. The waterfall approach is not recommended for complex projects.

7.3.2 Vee Model

The Vee model has become the standard ITS project development method. Figure 7.4 shows a typical adaptation of the Vee model for ITS project development. The left wing of the Vee model represents regional ITS architecture and feasibility study/concept exploration. The central part of the Vee model consists of the concept of operations, system requirements, design implementation, and verification and validation processes. Note that each process before implementation corresponds to a specific validation and verification process after implementation. The right wing of the Vee model represents operations and maintenance, changes and upgrades, and ultimate retirement of the system. The left side of the Vee model represents development of a project from a general user view to a detailed specification of the system design. The progression on the left of the Vee model is downwards through decomposition of the system into subsystems and the subsystems into components. The requirements are also decomposed into more specific requirements linking to system components. The hardware and software implementation is performed at the bottom of the Vee model. On the right side of the Vee, the system components are integrated and verified in an iterative manner. At the end, the completed system is validated to determine how well it meets the user's needs (National ITS Architecture Team, 2007).

The Vee model is recommended for high-risk ITS projects. The attributes that define a high-risk project include (Vollmer, 2015):

- The project scope is multi-jurisdictional or multimodal.
- The project scope requires developing a custom software program.
- The required hardware or communications technology are relatively new (i.e., not commonly used).

- It is required to have new interfaces to integrate with other systems.
- Systems requirements are not well understood or fully documented from the beginning of the project.
- Operating procedures are not detailed or fully documented.
- Some technologies are near to end-of-service life and likely to change.

Depending on the detail of requirements established beforehand, the Vee systems engineering process can be either once-through or evolutionary. When project requirements are well understood and documented and not subject to change, a single pass of the Vee model is sufficient for project implementation. When project requirements are not well understood at the beginning and the requirements are likely to be developed by learning and progression, the Vee model needs to be repeated after each deployment. Multiple passes through the Vee model, defined as the evolutionary approach, is essential for highest-risk projects.

Consistent with Federal regulations (23 CFR § 940.11), FDOT has developed a statewide Systems Engineering Management Plan (SEMP) for Florida. The SEMP provides technical guidance to manage, develop, and deploy ITS projects using systems engineering principles in Florida. The document intends to serve the ITS community for implementation of a system with a minimum budget and schedule while maximizing the quality (FDOT, 2005).

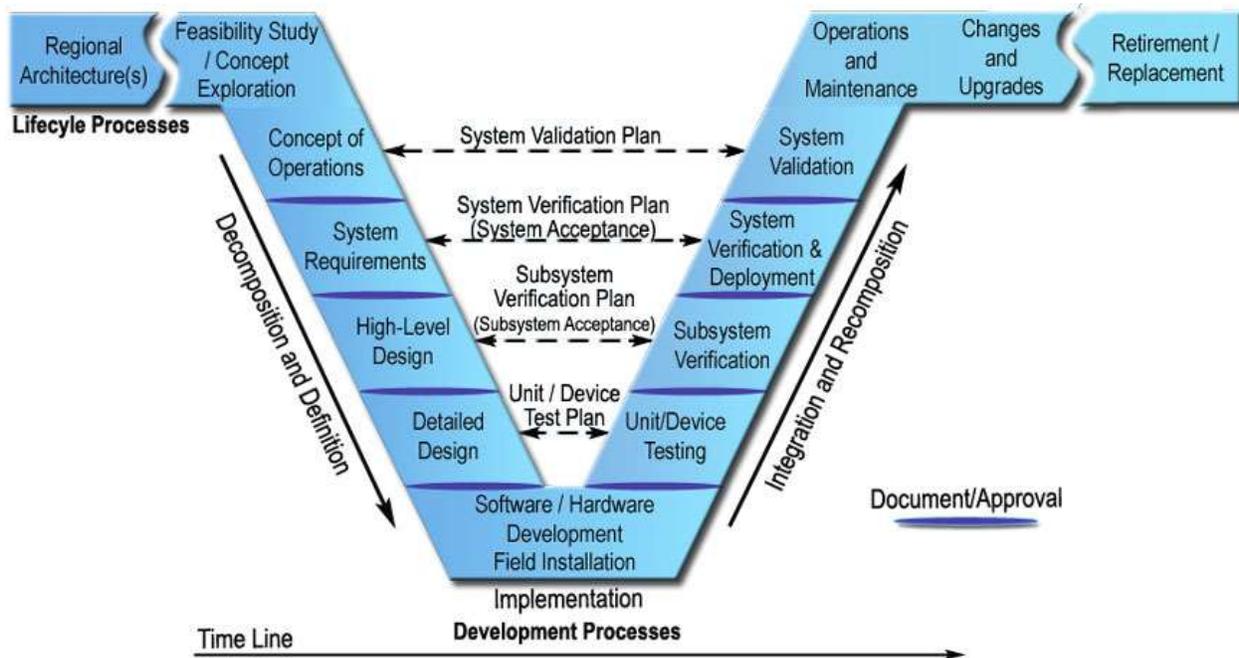


Figure 7.4: Systems Engineering Vee Diagram
(Source: National ITS Architecture Team, 2007)

FDOT's existing procurement processes are more aligned with the Waterfall approach, where linear sequential steps are followed in the project development process, with few to none opportunities to change once a contract is procured. For example, the steps constitute creating a concept, followed by designing the concept, and then constructing the design. Depending on the procurement process, if the process is Design-Bid-Build, then once the concept is finalized, FDOT advertises for a design based on the initial concept. There is no much opportunity to change the concept in the design phase, and even less scope to change in the construction phase.

As discussed in the previous sections, it is recommended to adopt the Waterfall model for low-risk ITS projects, and the Vee model for high-risk projects. When the project requirements are subject to change, as in the case of most of the ITS projects, it is recommended to adopt the evolutionary Vee approach.

7.4 TSM&O Project Development Process

A recent FDOT project entitled "Expanding Transportation Systems Management and Operations (TSM&O) from Planning to Construction Primer" provides guidelines to apply TSM&O strategies in all phases of a transportation project, from planning to construction (Abou-Senna et al., 2015). The study proposed adopting the Vee model for TSM&O project development processes, as shown in Figure 7.5. Project phases on the left are referred to as *Conceptualization* phases, and those on the right are referred to as *Implementation* phases.

Specific activities related to each phase, department(s) responsible to perform the activities, and potential involvement of stakeholders to maximize the project output are discussed in the following subsections. The TSM&O project development cycle includes the following phases:

- System-wide Evaluation
- Project Concept
- Programming
- Planning
- Preliminary Design, and PD&E projects with TSM&O strategy considerations
- Final Plans, Final Design, and Specifications
- Construction
- Operations
- Maintenance

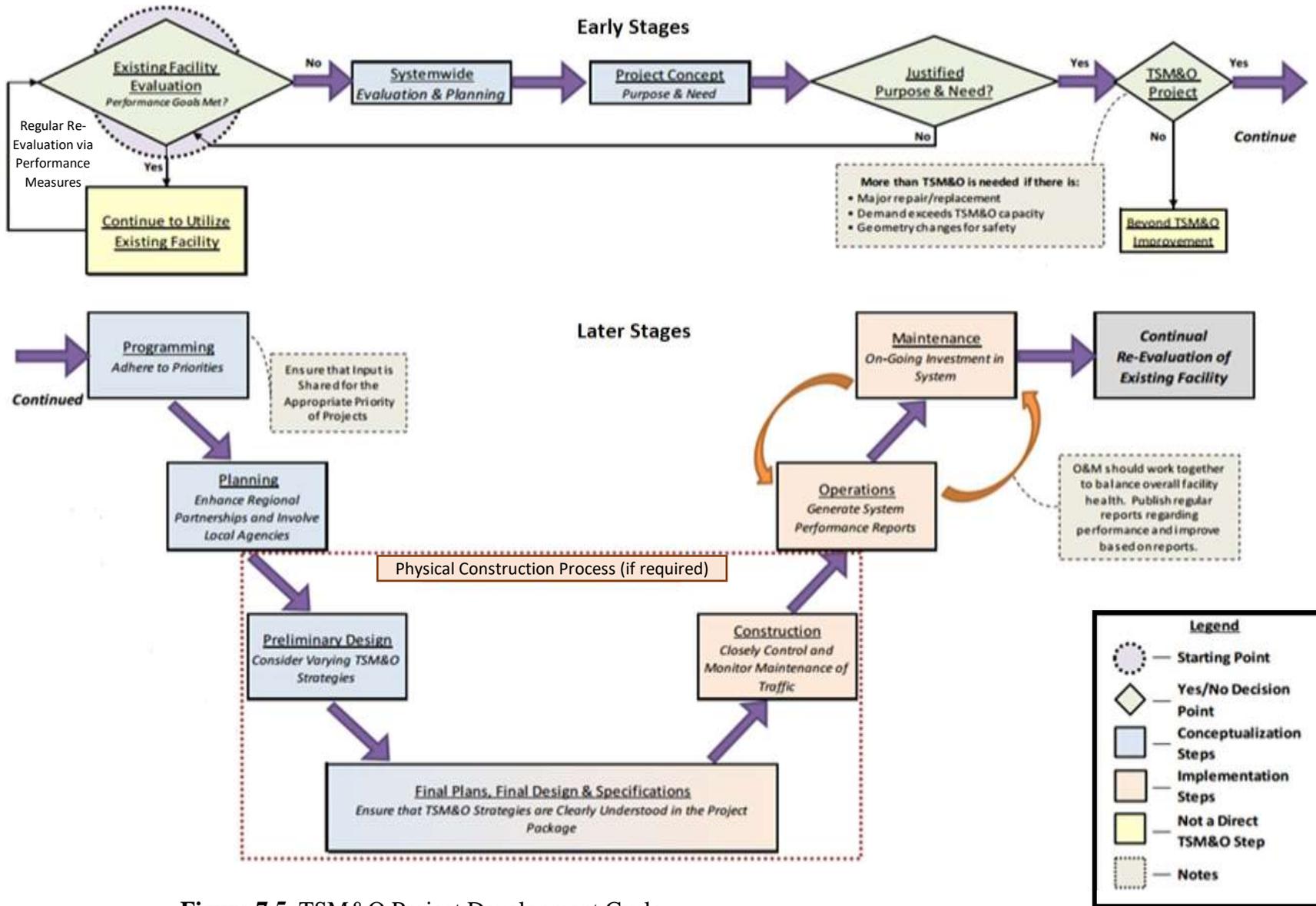


Figure 7.5: TSM&O Project Development Cycle
(Source: Abou-Senna et al., 2015)

7.4.1 System-wide Evaluation of Existing Facility

The condition and performance of the existing facility should be regularly assessed to realize whether established performance criteria are met. If the performance measures indicate that the existing facility requires improvements to meet public needs, TSM&O strategies should be considered in the determination of a project. Potential TSM&O applications should be evaluated not only for the facility alone, but also for the overall transportation system with multiple facilities.

- **Primary Agent:** Traffic Operations and Maintenance departments of an agency are primarily responsible for evaluating the existing condition.
- **Stakeholders' Involvement:** MPOs, tolling authorities, transit agencies, local agencies, and other departments that might have active participation in later stages should be involved in the review and assessment of the existing facility and the need for improvements.

7.4.2 Project Concept

A range of all pertinent TSM&O strategies should be explored to develop project concepts. The essential part of this phase is to develop a *Purpose and Need* statement that lists potential solutions for the identified concerns of the facility. This statement serves as a guiding principle for the project and connects the project objective to one or more of the following TSM&O benchmarks or goals: improve travel time reliability; reduce crashes; improve transit on-time arrival; expand modal choice; reduce travel delay; reduce fuel use; reduce air pollution; and reduce greenhouse gas emissions (Abou-Senna et al., 2015).

- **Primary Agent:** Planning department is primarily responsible for assessing the feasibility of TSM&O strategies and developing the project concept.
- **Stakeholders' Involvement:** All other departments that might have active participation in later stages should be involved in preparing the *Purpose and Need* statement during this phase.

7.4.3 Programming

The Programming phase involves prioritization of TSM&O projects so as to ensure timely completion. Oftentimes, TSM&O projects require deployment of technologies in the field within a limited timeframe. Delaying a project that needs immediate attention to meet public needs may invalidate the purpose and need of the project. A work plan should be established based on the

effectiveness and logical progression of the projects and their opportunity for potential associations with other projects.

- Primary Agent: Planning department is primarily responsible to determine the priority level of TSM&O strategies.
- Stakeholders' Involvement: MPOs, tolling authorities, transit agencies, local agencies, and other departments that might have active participation in later stages should be involved in prioritizing the project.

7.4.4 Planning

In the Planning phase, the *Purpose and Need* statement is analyzed, and the choice of alternative is specified. The extent of the project is identified, whether large or small, to suggest the course of action. If the project is small, some phases may be skipped, as applicable.

- Primary Agent: Planning department is primarily responsible for activities in the Planning phase.
- Stakeholders' Involvement: A collaboration between the Design, Operations, and Maintenance departments is essential to gather information that maintains the flow of the project with full understanding of the project goal. In addition, the Environmental Management office should be involved to ensure that the TSM&O project meets environmental standards.

7.4.5 Preliminary Design

The Preliminary Design phase involves preparing an initial design of the TSM&O project, and/or the PD&E project with TSM&O strategy considerations. Although one alternative is suggested in earlier phases, a re-inspection of all the alternatives should be done from a design perspective. This will aid in finding a preferred alternative based on the most effective design.

- Primary Agent: The Design department is primarily responsible for preparing the preliminary design.
- Stakeholders' Involvement: Planning department should be encouraged to remain involved in this stage to confirm that the TSM&O benchmarks are followed, and the design supports the purpose and need of the project. Construction department should also be involved to discuss constructability and assess the plans for construction efficiencies. Survey and Mapping departments could be involved to provide

guidance on the available right-of-way. Drainage department should be involved to obtain information on drainage facilities and adequate channelization options.

7.4.6 Final Plans, Final Design, and Specifications

In this phase, the plans, design, and specifications of the TSM&O project are finalized for construction. The final design documents are prepared after investigating the impact of all design-related changes to the project. These documents should include the assumptions made to measure the effect of changes in design elements and the verification and validation processes relating to the changes.

- **Primary Agent:** Design department, Environmental Management office, and right-of-way team are primarily responsible for finalizing the design document.
- **Stakeholders' Involvement:** Construction department should be actively involved in reviewing the plans, design, and specifications of the TSM&O project since they are the primary agents for delivering the finished product. Materials department should also be involved to provide feedback regarding materials that may affect performance measures.

7.4.7 Construction

TSM&O strategies are executed during this phase. Performance measures specific to construction projects should consider how well the existing facility is being operated during construction.

- **Primary Agent:** The Construction department is the primary agent to accomplish the construction work.
- **Stakeholders' Involvement:** Operations and Maintenance departments should be involved and regularly updated about the progress of the construction work. This is to ensure that the project execution is consistent with the original goal. Their role can be extended to develop a list of items that can be addressed by the Construction department to avoid cascading issues. Environmental Management office should also be involved for assessing environmental concerns during construction.

7.4.8 Operations and Maintenance

The Operations and Maintenance phases are closely connected in TSM&O/ITS projects. The interaction between operations and maintenance is essential to keep the facility functioning at optimal performance. A continued assessment of system performance in this phase allows a TSM&O project to improve and evolve. Small scale changes can also be implemented and deployed in this phase.

- **Primary Agent:** Operations and Maintenance departments and emergency management partners (e.g., law enforcement, first responders, road rangers, etc.), are primarily responsible for operations and maintenance of TSM&O/ITS projects. They should also review whether all the agreements are correctly executed. The ITS department also has a major role to ensure operation of communication devices and generation of reliable data to measure the system's performance. Because of their close involvement in daily operations, the groups together should assess the facilities on a regular basis and provide recommendations for improvements.
- **Stakeholders' Involvement:** Appropriate departments should be involved to gain information as lessons learned from issues addressed by the Maintenance department.

7.5 Survey on Project Development Methods Used in TSM&O/ITS Projects in Florida

A survey questionnaire was administered to obtain information regarding specific challenges experienced with the current project development process used for district-and state-level ITS, ATMS, and TSM&O projects. Projects that involved, or are currently in the process of, developing software tools were of particular interest. The research team had a meeting with the Project Manager, the Co-Project Manager, and the FDOT ITS Software and Architecture Coordinator to identify relevant projects and discuss the draft questionnaire. The projects that were identified during the meeting include:

- Maintenance Information Management System (MIMS)
- Operations Task Manager (OTM)
- Central Florida Regional Integrated Corridor Management System (ICMS)
- Active Arterial Management (AAM)
- Intersection Movement Counts (IMC)

Once the questionnaire was finalized, it was emailed to the corresponding project managers requesting them to share their experiences while managing these projects. The following

subsections provide a brief overview of the selected projects, and discuss the survey questions and responses.

7.5.1 Software Development Projects

An overview of the aforementioned ITS, ATMS, and TSM&O software development projects is given below:

- **Central Florida Regional Integrated Corridor Management System (ICMS):** FDOT D5 has initiated the process of developing software technologies for the ICMS as part of a statewide integrated corridor management program. At a minimum, the ICMS will consist of; COTS modeling software, a custom-built decision support system (DSS), and a custom-built information exchange network (IEN) subsystem that includes dashboards and other user interfaces to the system, and a data fusion environment (DFE) to host data sources for both the ICMS and other external users and applications (FDOT, 2017i).
- **Maintenance Information Management System (MIMS):** The MIMS is an inventory tracking software deployed by FDOT D4. According to the FDOT D4 Standard Operating Guidelines, MIMS “is used to automate, centralize, and streamline the maintenance of ITS devices and respective SunGuide software subsystems. MIMS was designed to facilitate the maximization of system uptime and to be the technological glue that ties together operations and maintenance staff. The MIMS automates the dispatch of technicians for preventive and responsive maintenance activities, tracks maintenance activities and parts inventory in near real-time, and provides representative reports for maintenance activities and inventory management. MIMS is compliant with SunGuide software. MIMS also includes the Maintenance and Inventory Mobile Application (MIMA). The MIMA allows technicians to remotely communicate with SunGuide in near real-time allowing the exchange of data related to trouble tickets, preventive maintenance tickets, GPS receiver position data (from the technician’s laptop), and parts inventory” (FDOT, 2010). Note that SunGuide software, which is an ATMS software, is implemented in all regional Transportation Management Centers (TMCs) within Florida to monitor and manage roadside sensors, cameras, and ITS devices. The software allows FDOT to effectively detect and respond to incidents and exchange data among the TMCs (SunGuide Software, 2017).
- **Operations Task Manager (OTM):** The OTM is software developed by FDOT D6 to manage express lanes and ramp signaling systems, as well as to help support with enhanced incident management and advanced traveler information services. OTM is designed in a modular form to establish support for new projects when added. OTM currently features ten modules through an easy-to-use interface. The one-stop operational dashboard helps streamline certain functions and automate manually-intensive tasks for the operations team, thus saving time and providing increased service output (FDOT, 2013a).
- **Active Arterial Management (AAM):** The AAM system is being developed by FDOT D5 to assist in managing key corridors in the Metro-Orlando region. The system will monitor

arterial roadways to promote better synchronized traffic signals, coordinate activities across jurisdictional boundaries, suggest operational modifications, and develop timings for incident management, construction, and special event activities. The system is planned to be deployed first in Orange and Seminole Counties (FDOT, 2016f).

- Intersection Movement Counts (IMC): The IMC project is being developed to “provide an automated method via software and/or hardware to determine intersection movement counts. These automated counts will serve as a real-time resource for the real-time active monitoring and management for some of the AAM specific arterial roadways within FDOT D5. The IMC project focuses on 32 signalized intersections within the cities of Orlando, Winter Park, and Maitland along three major arterial roadway corridors” (FDOT, 2016f).

7.6 Survey Questionnaire

The survey questionnaire was divided into three broad sections: Project Overview, Project Requirements, and Project Implementation. A sample of the survey questionnaire, including the invitation for participation, is provided in Appendix I. Survey responses are discussed in the following subsections. Project managers that responded include:

- Mr. Dong Chen from FDOT D4 responded about MIMS
- Mr. Javier Rodriguez, P.E. from FDOT D6 responded about OTM
- Ms. Jennifer Fortunas, P.E. from FDOT Central Office responded about OTM express lanes module change management
- Mr. Clay Packard, P.E. from Atkins responded about ICMS

7.6.1 Project Overview

This section focused on the project objective, the project team, and the project delivery system used in the project. A total of seven questions were asked in this section. Questions and responses are listed below.

1. *What was the objective of the project that you were recently involved in?*
 - The objective of the MIMS project was to assist asset inventory management, asset auditing, management of asset related issues, preventative maintenance management, management of the ITS maintenance contract activities, track response and completion times, and other asset management related metrics.
 - The objective of the OTM project was to integrate multiple software tools into one platform to improve operational efficiency and dynamically develop new and enhanced capabilities.

- The objective of the OTM express lanes module change management project is to embed statewide express lanes software into the OTM to expand its use in all express lanes projects throughout the state.
- The objective of the ICMS project was to improve information sharing, travel time reliability, and incident management; increase corridor throughput; and help travelers making intermodal travel decisions.

2. *What was your role in this project? Could you please elaborate on your responsibilities in this project?*

- Mr. Chen is the Project Manager for the MIMS project. Mr. Chen has supervised the design, development, testing, integration, deployment, and maintenance of MIMS software.
- Mr. Rodriguez is the FDOT D6 Program Manager for the OTM project. Mr. Rodriguez was responsible for providing high level direction and approval to the project team, allocating necessary funding, reviewing schedule, and ascertaining overall progress.
- Ms. Fortunas is responsible for the change management plan and conducting meetings with the change management team who will identify enhancements to the software.
- Mr. Packard is the Consultant Project Manager for the ICMS project. Mr. Packard coordinated with the FDOT project sponsor to implement the agency's vision in the scope of services document and the requirements document. He also coordinated with the District Five Procurement office to setup and execute an invitation to negotiate.

3. *Who else from the state or the district level were involved in the project?*

- The FDOT asset maintenance contract manager was involved in the MIMS project, and the FDOT ITS staff were involved in the OTM project. Staff involved in the OTM express lanes change management project include one representative from each FDOT district that has an express lane project, two representatives from FDOT Central Office Traffic Engineering and Operations, two representatives from FTE Engineering and Operations, two representatives from Florida's Turnpike Tolls, and two representatives from FDOT Central Office Transportation Technology. Several persons from Central and District Offices are currently involved in the ICMS project, including members from the technical review committee, FDOT project manager, procurement officer from D5, and technical advisor from D4.

4. *Was the project objective clear to everyone involved in the project?*
 - The response was affirmative from all the four project managers.
5. *Did you feel that some other personnel could provide valuable inputs and, therefore, should have been involved in the software development process?*
 - The project managers asserted the involvement of all relevant stakeholders and software expertise who could contribute to the projects.
6. *Which delivery system (e.g., design-build, design-bid-build, design sequencing) was used for this project?*
 - Different delivery systems were adopted for each project. A contractual task work order was used for the MIMS project. The Agile method was used for the OTM project. The Design-build method with an invitation to negotiate was used for the ICMS project.
7. *Did you feel that the project could be benefitted more if a different delivery process was undertaken?*
 - The project managers of the MIMS and OTM projects did not agree that a different delivery process could benefit the project. In other words, the delivery method used in the corresponding project was deemed appropriate. Note that the ICMS project is currently in the initial phase to make comments on whether a different delivery process could benefit the project.

7.6.2 Project Requirements

Typically, several project requirements are set at the beginning of the project, and the project is carried out to meet those requirements. The project development process is typically sequential, meaning that the next step is not initiated until the current step is completed. Generally, the steps include requirements analysis, design, coding, integration, testing, and deployment (see Figure 7.2). However, in some situations it is inevitable that project requirements need to change, which may impact the overall project in terms of cost and on-time delivery. A total of 11 questions were asked relating to the project development process used in the project and the challenges involved in meeting project requirements. Survey questions and responses are listed below. Note that the OTM express lanes module change management is currently in the initial stage and therefore, most of the questions in this section were not applicable to this specific project.

8. *What were specific requirements of this project related to software development or updates?*

- The specific requirements of the MIMS software development project was to use agile development methodologies, embedded within a traditional systems engineering model.
 - The requirements of the OTM software development project were very specific for some programs (e.g., express lanes ITS maintenance) from the concept of operation to the testing phase, while no specific requirements were defined for other OTM programs (e.g., graphical user interface, incident detection, etc.).
 - No specific requirements were developed yet for the OTM express lanes module change management project.
 - The specific requirements of the ICMS software development project were to use systems engineering process to develop the three subsystems, including COTS modeling software, DSS, and IEN, which require software development, integration, and maintenance.
9. *Did the development team ask for any clarifications on the requirements? In other words, did you feel that the requirements were well understood by the development team up-front?*
- All the requirements of the MIMS project were not set up-front. The requirements evolved as the project grew. A collaboration between FDOT and the contractor that developed the software was present to realize the requirements. A continuous interaction happened between developer and end-user of the OTM project to realize its requirements. A few questions on the requirements of the ICMS project were raised during the advertisement phase prior to the statement of qualifications questionnaire responses.
10. *Did the software development or updates follow the Systems Engineering Process (e.g., Vee Development Model)?*
- The MIMS project was developed using agile development methodologies embedded within the traditional systems engineering process. Of ten modules in the OTM software, two modules, one for express lanes and the other for ITS maintenance, were developed following the systems engineering process. The ICMS software development project intends to follow the systems engineering process.
11. *Did any changes (e.g., modifications or additions) in project requirements occur midway through the project? If yes, then please answer the following questions:*
- (a) *Who first did feel the need for this change and at which stage of the project?*
 - (b) *Who were responsible to make the changes happen?*
 - (c) *What was the impact of the change(s) on other steps of the project?*

- The requirements for MIMS project evolved through the design and development stages. It was expected from the early stage that requirements would be added as the project advanced. No more specifics were given about who identified and initiated the need for change, and the impact of those changes on the project.
- The OTM project was built on the assumption that requirements would change as the project made progress. A base set of requirements were defined first, and then there were frequent interactions between developer and users.
 - o The changes were initiated by the one who identified the need first and those occurred at every stage of the project.
 - o Some changes were made at an early stage of the project while others were not made immediately. Some changes were incorporated into the current release and some were deferred to the next release.
 - o The development team and end users would assess impact (benefit, schedule, risk of both implementing and not implementing the change) and relay to management for direction. When identified early, there was often little impact. Development of test plans was usually deferred as late as possible in order to allow requirements to solidify, although changes with significant impact didn't happen late in a release cycle.

12. Do you think that some other requirements could be added to the project at the time the projects reached the testing phase?

- There were no changes in project requirements after the MIMS project had arrived at the testing phase. Some of the requirements in the OTM project were updated during the testing phase.

13. How much time was spent in the testing stage to ensure that the product met the requirements?

- The end users spent a minimum of two weeks to test the MIMS software on a local environment. Prior to releasing an OTM software update, the testing phase was kept no more than two months. Note that the question is not applicable to the ICMS project as it is currently in its initial phase.

14. Who was responsible for the testing?

- The contractor was primarily responsible for testing the MIMS software. Selected stakeholders could also provide feedback after testing. The degree of responsibility varied between end-user and people to test the OTM software.

15. What evaluation criteria were used for testing?

- The evaluation criteria for the MIMS software testing depended on test plans and scenarios. Similarly, the OTM software was tested based on a wide range of evaluation criteria, including functional, user interface, compatibility, and performance.

16. Were the criteria sufficiently performance-based?

- The test criteria for the MIMS software were performance-based, while those for the OTM software were performance-based only when performance such as execution time and responsiveness is the main concern.

17. Did you feel that any other evaluation criteria could also be used?

- According to the project manager, the following criteria could have been used for the OTM project: “Since the development approach was intended to be iterative, the focus could be on the highest priority criteria and then others could be assessed and, if needed, addressed incrementally. This often moved the focus from estimating or guessing what would happen to observing what actually happened and correcting, if needed. The same would have occurred if the estimates were wrong. We could just get there sooner.”
- At this point, the ICMS project managers are considering two criteria: stakeholders to conduct usability test, and data scientists to test the suitability of the environment for conducting data analytics.

18. Did you know whether the product (i.e., software) kept provisions to incorporate future technical innovation?

- All the three software applications, MIMS, OTM, and ICMS, are designed in a modular fashion to allow for future enhancements. However, the degree of the OTM software scalability varies; for example, the tolling algorithm does not have the flexibility while the operations quality control module does have the provisions for future enhancements.

7.6.3 Project Implementation

This section focuses on the project duration and flow, project meetings, communications among team members, and the survey participant’s view on how to improve managing a software development project. A total of 12 questions were asked concerning project implementation. Note that both the OTM express lanes module change management and the ICMS projects are in the initial stages and, therefore, several questions were not applicable to these two projects.

19. *What was the planned duration of this project? Was it a high-risk project?*

- The MIMS software development project was a low-risk project and the project timeline was short, approximately 12 months from approval to deployment. The OTM project started in 2010 and still is ongoing. The OTM express lanes module change management project, which started in 2016, is not a high-risk project. The projected duration of the ICMS project is five years, including two years for development and three years for support. A longer duration of the OTM and ICMS software development projects is attributed to them being high-risk projects.

20. *Was the project delivered on time according to schedule? If not, what do you think are the main reasons behind the delay?*

- The MIMS project was delivered on time. On the other hand, the OTM project had experienced significant delays for two reasons. One reason entails to the necessity of reconstructing the pre-established requirements for one of the modules as the requirements were found to be inadequate. Another reason was due to allocation of less time and fewer resources for software testing, while the process actually required much more time and resources. In addition, a planned release on several occasions was deferred to a subsequent release to avoid schedule risk.

21. *Did the development team inform you about the progress at regular intervals?*

- For both the MIMS and OTM projects, the progress was regularly informed.

22. *Did you feel you were always kept informed of the progress?*

- Both the project managers of the MIMS and OTM projects were fully aware of the project's progress at any point in time.

23. *How many meetings were held over the project span from planning to delivery?*

- There were weekly ITS program meetings in which the progress of the MIMS project was discussed. Meetings specific to the MIMS project were only held to review the user interface system. On the other hand, many formal and informal meetings were held by various groups during the OTM project life cycle. For the OTM express lanes change management project, meetings were scheduled every quarter with at least one face-to-face meetings each year.

24. *Were the meetings pre-scheduled as in the project contract or on-demand?*

- Both pre-scheduled and on-demand meetings were held for the MIMS and OTM projects. For the OTM express lanes module change management project, the meetings are often pre-scheduled.

25. *At what frequency were the meetings held?*

- The frequency of regular meetings varied by projects. For example, the OTM project had held high-level meetings and status-update meetings each month, while the MIMS project held weekly meetings. On the other hand, the OTM express lanes module change management project had quarterly meetings.

26. *Who usually were present during the meetings?*

- Depending on the nature of the meetings, team members and different stakeholders were present during the meetings.

27. *Did you feel the project went smoothly?*

- It was agreed that both the projects were accomplished at a smooth pace.

28. *What were the specific impediments faced by the project team during the implementation of the project objective?*

- The main constraint of the OTM project was to maintain compatibility with the software outside of the team's control. In addition, some of the key contributors' workload raised concerns at times. The MIMS project had not encountered any specific constraints.

29. *What steps you consider could have been taken to improve the project and optimize benefits from the project?*

- Two different and appealing ideas to improve the project and optimize its benefits emerged from the project managers' responses. One is through the involvement of more interested stakeholders from other agencies and districts across the state. Another is having more staff in the development team to reduce extra workload.

30. *What do you consider as being the lessons learned in this project?*

- Lessons learned from the MIMS and OTM projects are listed below:
 - o A forum need to be established for state-wide initiatives.
 - o When requirements are driven by a small group that can work closely with developers and testers, new capabilities that address the users' needs can be delivered rapidly, and the overhead and risk involved in defining, developing and deploying these capabilities can be reduced significantly. Project requirements must still be established as well as possible and before beginning the development. The flexibility to adapt must be limited to those things that could

not be identified in advance or would have required more time to define, usually because of lack of sufficient information in advance.

7.7 Chapter Summary

The Florida TSM&O Strategic plan identifies the opportunities to consider TSM&O strategies under each phase of the project development cycle, including planning, PD&E, design, construction, operations, and maintenance (FDOT, 2013c). However, there are no established guidelines specific to TSM&O projects. Since TSM&O projects resemble ITS projects to some extent, the project development methods for ITS projects in Florida were reviewed. ITS projects using highway trust funds, according to Federal regulations (23 CFR § 940.11), must be developed based on a systems engineering process. Accordingly, FDOT has developed a statewide Systems Engineering Management Plan (SEMP) for ITS projects in Florida.

The underlying concept of the systems engineering approach is to identify stakeholders, determine needs, and then follow a logical process of developing the concept of operations, system requirements, functional design, and implementation followed by a series of verification and validation measures to ensure that the system meets stakeholder needs. The Vee development model represents this key concept in the SEM. A recent FDOT study proposes the Vee model framework as being compatible for TSM&O projects in Florida. This compatible Vee model divides the TSM&O project development cycle into two phases: *Conceptualization* and *Implementation*. Existing system-wide evaluation, statewide evaluation and planning, project concept, programming, planning, and preliminary design fall into the *conceptualization* phase. Construction, operations, and maintenance fall into the *implementation* phase, and final plans, final design, and specifications are a blending of both phases. The systems engineering Vee model is followed by FDOT for various software-related projects developed at the district- and state-levels.

A survey was conducted to obtain information regarding specific challenges and shortfalls with the current project development process used for district- and state-level ITS, ATMS, and TSM&O projects. The survey focused on current projects, or recently completed projects, that involved the development of software tools. The following project managers responded to the survey questionnaire:

- Mr. Javier Rodriguez, P.E. and Ms. Jennifer Fortunas, P.E. responded about OTM.
- Mr. Clay Packard, P.E. responded about ICMS.
- Mr. Dong Chen responded about MIMS.

Key findings from the survey include:

- In addition to the systems engineering Vee model, agile methodologies are adopted for software development projects.
- The strategy to define requirements as the project progresses may provide a significant benefit depending on the purpose of the project. In the case of deploying recent and

advanced technologies, the requirements if set early, may impede the overall project flow as changes are likely to occur.

- Allocating enough time for testing a system in-house, and by the end user, is essential for a successful deployment of the system.
- Frequent meetings will help in keeping all relevant stakeholders updated, resolving any issues raised by stakeholders, and solving other difficulties (e.g., resources) in the development without creating delays. This practice can promote a smoother pace for the project.
- Involvement of relevant stakeholders from different agencies is a key factor in improving the project to optimize benefits.
- Sufficient in-house staff should be involved to distribute workload.
- A forum should be established for statewide initiatives.
- When requirements are driven by a small group that can work closely with developers and testers, new capabilities that address the end users' needs can be delivered rapidly, thus significantly reducing the overhead and risk involved in defining, developing and deploying new capabilities.
- Whenever possible, project requirements should be well established before beginning the development. The flexibility to adapt to project requirements must be limited to those things that could not be identified in advance due to lack of information.

8 – AGILE APPROACH FOR TSM&O PROJECTS

Several solutions used today to improve mobility and reduce congestion are in fact TSM&O strategies. TSM&O strategies that employ ITS include using variable speed limits, implementing adaptive traffic control systems and ramp metering, and identifying and relaying information on traffic incidents and detours. Deploying these types of TSM&O/ITS strategies present unique challenges. For example, identifying and responding to traffic incidents requires the collection and analysis of large amounts of real-time data, often from a wide array of sources. As such, these types of transportation management strategies are usually software-intensive.

Project development approaches used for the majority of roadway projects have typically been adopted for software-intensive TSM&O/ITS projects. Oftentimes, this practice has resulted in a product that is not what the agency expected or is already obsolete at the time of deployment. TSM&O/ITS projects cannot be developed using traditional approaches, especially since the technologies involved can significantly change over time between initial conception and project completion. Although agencies begin the process with the end result in mind, all of the project requirements may not be well defined at the beginning of the development process. In other words, some of the features and requirements that need to be addressed to meet the needs of the end users may not be clear at the onset. Thus, traditional project development approaches are not suitable for developing TSM&O/ITS projects.

An alternative approach to TSM&O/ITS project development is the Agile methodology. In 2001, a group of software developers convened to establish the values and principles of Agile methodology to guide the software industry to a more value-driven, change-oriented, collaborative, and faster approach for software development (Rigby et al., 2016a). Since then, Agile has gained much popularity among IT professionals for software development projects. Other industries have also adopted this approach because of its more result-oriented approach. Examples of such industries include marketing, logistics, machine production, warehousing, and education (Rigby et al., 2016b).

This chapter discusses Agile methodology and evaluates the Agile approach for TSM&O/ITS projects. Information is organized as follows:

- Section 8.1 describes Agile values, principles, and their differences with the traditional “Waterfall” approach. Popular Agile development methodologies, and how Agile is being adopted in the private sector are discussed.
- Section 8.2 presents a detailed description of the Scrum approach, the most popular variant of Agile methodology.
- Section 8.3 discusses the Scrum approach using a sample hypothetical TSM&O/ITS project.
- Section 8.4 discusses how to embrace Agile in government organizations, with a focus on TSM&O/ITS projects.

- Section 8.5 summarizes this research effort, and provides recommendations.

8.1 Agile Process

Traditional projects follow a sequential development plan; the common form of which is known as the “Waterfall” method. As the name implies, in the Waterfall development approach, the steps involved progress downward, starting with Requirements Analysis, followed by Design, Coding, Integration, Test, and culminating in Deployment (see Figure 7.3). In this approach, no step can be initiated before the current step has been completed. The requirements are finalized at the beginning of the process, and the plans to execute the work are intended to be fixed. Therefore, any changes that appear important midway or later in the project cycle involve extra cost to implement.

An alternative to the Waterfall approach is the Agile approach which suggests an iterative and incremental method to execute the work. With Agile, some of the requirements are not determined up front, rather they are added when more knowledge can be gathered as the project progresses. A complete product is developed in pieces, or increments, where the most important elements are built first. Each increment is planned, designed, coded, and tested so that feedback from the end users and stakeholders can be iteratively incorporated. This approach, therefore, allows for changes to occur with relative ease. Since change is inevitable, especially for non-traditional projects, accommodating the changing requirements in a traditional project management process is often costly. The Agile approach offers more flexibility to incorporate changing requirements through a philosophy of frequent develop-evaluate-adapt cycles, resulting in a more budget-friendly environment.

Figure 8.1 illustrates the Agile approach. In the project management process, the main features of Agile include:

- Adaptation to changing requirements,
- Encourage self-organizing teamwork, and active participation of users, stakeholders, customers, and
- Ensure quick completion through a small time-boxed work flow.

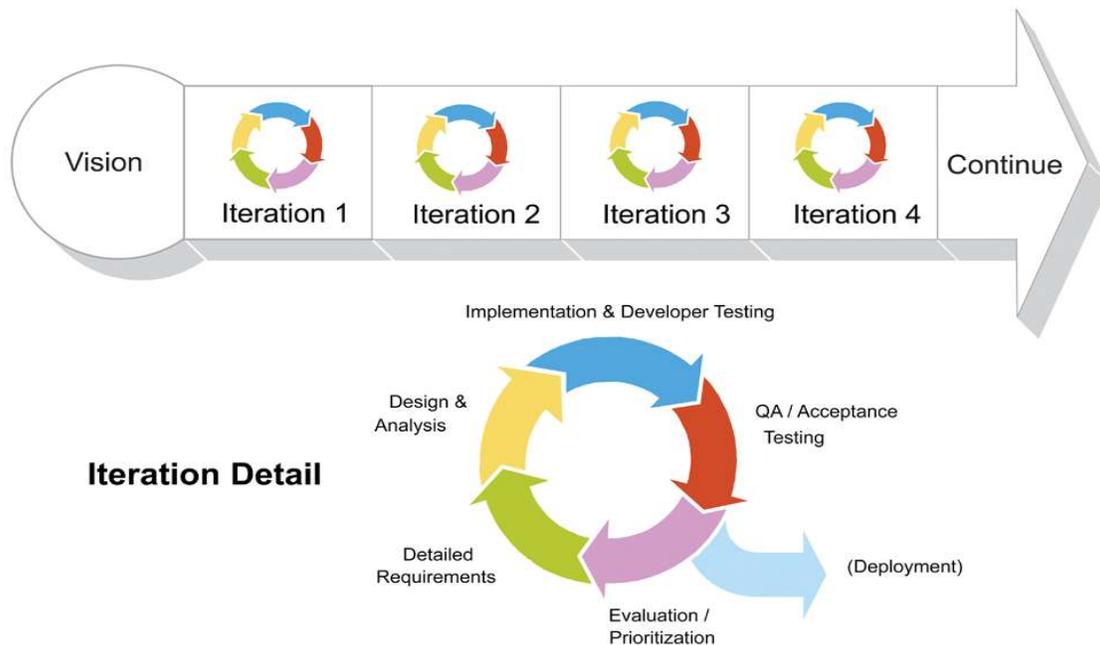


Figure 8.1: Agile Approach
(Source: James & Walter, 2010)

8.1.1 Traditional vs. Agile Process

The goals of transportation projects focusing on TSM&O/ITS strategies are usually well-defined. For example, the goal can be to develop a new system or to enhance an existing system with new features. However, some system features may not be identified during the conception phase, and may need to be added or modified as the project develops. Moreover, the detailed development requirements of some system features also may not have been identified at the conception phase. Unlike the traditional plan-based approach where plans and requirements are made up front based on the assumption that all information required to develop a product is known and correct, the Agile approach can be adopted when only some requirements and plans are developed up front, with more details to be included in the requirements as the project progresses. For example, the traditional approach requires decisions to be made, reviewed, and approved within their respective phases, and changing the approved requirements at later stages is often costly. The Agile approach has the ability to leverage this uncertainty by employing iterative and incremental development steps that require breaking the project into smaller pieces. This gives the opportunity to learn incrementally and apply what is learned to future steps.

Unlike the traditional approach which progresses per a set schedule identified at the beginning of the project, the Agile approach progresses by frequent and quick feedback from stakeholders. Agile methodology focuses on working quickly (but not hurriedly) to develop, deliver, and obtain feedback fast, and test the product at the end of each iteration. This approach assists in identifying and fixing problems at the early stages, unlike the traditional approach where testing is done at the end of the development cycle. Additionally, the traditional approach is document-

centric and process-heavy, whereas the Agile approach is value-centric, with more emphasis placed on the value the product gives to the end user rather than on documentation and process.

Table 8.1 summarizes how the traditional approach differs from the Agile approach, and presents a comparative picture in terms of the different attributes associated with the project development process.

Table 8.1: Comparison of Traditional and Agile Approaches (Source: Rubin, 2012)

Attribute	Traditional Approach	Agile Approach
Process structure	Phase-based and sequential.	Iterative and incremental.
Variability	Variability is eliminated by establishing a well-defined set of requirements and accepting little feedback from stakeholders later in the process.	Variability is controlled through inspection, adaptation, and transparency by receiving frequent and early feedback from stakeholders.
Uncertainty	Uncertainty about the features of the final product is removed first, followed by uncertainty about the processes and technologies to be used to develop a product.	Uncertainties are removed simultaneously using frequent and early feedback.
Plans and requirements	Plans and requirements are made up front based on the assumption that all information required to develop a product is known and correct.	Not all plans and requirements are required to be developed up front, and more details can be included in the requirements as the project progresses.
Decision making	Decisions at each phase are made before the start of the phase.	Options to make decisions are kept open until the last reasonable moment, when the cost of not making a decision becomes greater than the cost of making a decision.
Change	Change is disruptive to plans and expensive, requiring reshuffling of budget resources.	Accommodates changes in requirements by employing iterative and incremental development steps that require breaking the project into smaller pieces. This gives the opportunity to learn incrementally and apply what is learned to future steps.
Predictive vs. adaptive	Highly predictive.	Balance between predictive up front work and adaptive just-in-time work.
Assumptions and validation	Many important assumptions are embedded, with no validation until a later phase of development.	The number of important assumptions are minimized up to the point when they can be soon validated.
Learning	Critical learning occurs after one major analyze-design-code-test loop, which may result in insufficient time to leverage the learning.	Learning occurs by organizing the workflow for a fast inspect-adapt-assume-build-feedback loop. This gives the opportunity to learn incrementally and apply what is learned to future steps.

Table 8.1: Comparison of Traditional and Agile Approaches (continued) (Source: Rubin, 2012)

Attribute	Traditional Approach	Agile Approach
People vs. work waste	People are allocated to achieve high levels of utilization, with a focus on eliminating the waste of idle workers rather than that of idle work.	Focus is on idle work, not idle workers, as the cost of idle work can be more expensive than the cost of idle workers, and reduced efficiency may occur if everyone is kept busy 100% of the time.
Conformance to a plan	Conformance to a plan plays a major role in the project's success.	More attention is given on rapid re-planning and adapting to the emergence of important information rather than on conforming to a plan.
Progress	Progress is determined by completing a phase and being allowed to start the next phase.	Progress is measured by validating working assets that deliver value.
Centricity	Process-centric; development diligently follows the pre-identified process where the integration and delivery of features occur at the end.	Customer-value-centric; development follows a prioritized, incremental process to build and deliver high value features continuously. Priority is given to "must-have" features and not to "nice-to-have" features.
Speed	Idea is to do things right the first time and then move quickly from one step to the next.	Idea is to work quickly to develop, deliver, and obtain feedback fast, in several iterative loops.
Quality	Quality comes at the end, after an extensive test-and-fix phase.	Quality can be ensured from the beginning. Agile approach assists in identifying and fixing problems at the early stages, while the product is being developed in iterations.
Formality	Well-defined procedures and checkpoints are important to effective execution. The process is document-centric and process-heavy.	The process is value-centric, with more emphasis placed on the value the product gives to the end user rather than on documentation and process.

8.1.2 Agile Values and Principles

The *Manifesto for Agile Software Development*, also called the Agile Manifesto, was published in 2001, and presented Agile values and principles to follow for a better way of software development (Beck et al., 2001). Although the Agile Manifesto was originally developed with a focus on software development projects, any process that is aligned with the values and principles of the Agile Manifesto is referred to as an Agile process. According to the manifesto, Agile processes place value on:

- individuals and interactions over processes and tools,
- working software over comprehensive documentation,
- customer collaboration over contract negotiation, and
- responding to changes over following a plan.

In addition, the following 12 principles are described in the manifesto for the success of an Agile process.

1. Satisfy customers through early and continuous delivery of valuable work/product.
2. Welcome changing requirements at any stage of a project.
3. Deliver working product frequently, with a preference on the shorter timescale.
4. Ensure regular collaboration between the project team and business people, preferably on a daily basis.
5. Build projects around motivated individuals by providing them a suitable environment and the support they need, and have faith in them to get the job done.
6. Convey information to and within a development team through face-to-face conversation.
7. Measure progress by the amount of completed work that is of value to the customer.
8. Maintain a constant pace for sustainable work progress.
9. Pay continuous attention to technical excellence and good design for enhancing agility.
10. Maintain simplicity, the art of maximizing the amount of work not done. In other words, the team needs to focus more on the “must-have” features and less on the “nice-to-have” features to ensure that sufficient resources are allocated to the few truly valuable features that deliver the highest business value.
11. Build self-organizing teams to have the best outcome in plans, requirements, and designs. Note that the person who integrates all of the work is also part of the team, and this team is the superset of the Development team.
12. Retrospect previous steps at regular intervals to tune and adjust the team’s behavior to become more effective.

8.1.3 Agile Development Methodologies

Currently, the traditional Waterfall and Vee models, discussed in Chapter 7, are the most popular systems engineering project development models for ITS projects. Unlike traditional models, Agile methodologies offer flexibility in executing the work. The basic concept of the Agile approach is to offer an iterative and incremental development method.

There are several frameworks that follow Agile methodologies. Two popular Agile frameworks are *Scrum* and *Kanban*, discussed below. These frameworks could be adopted for TSM&O/ITS projects.

8.1.3.1 Scrum

Scrum is the leading Agile development methodology. It is not a technique that follows a series of sequential steps to build a product, rather it is a framework within which various techniques can be employed for organizing and managing the work. Scrum offers an iterative, incremental approach to optimize predictability and manage risk. It is also flexible and easy to understand. The Scrum approach focuses on providing transparency to the clients, the opportunity for clients to inspect the products during the development phase, and the ability to adapt to changing requirements. Section 8.2 discusses the Scrum approach in detail.

8.1.3.2 Kanban

Kanban is an Agile approach that is overlaid on an existing process. Described by Rubin (2012), key aspects of the Kanban approach require project management to:

- “visualize how the work flows through the system (for example, the steps that the support organization takes to resolve a support request)”,
- “limit the work in process at each step to ensure that you are not doing more work than you have the capacity to do”, and
- “measure and optimize the flow of the work through the system to make continuous improvements”.

Figure 8.2 illustrates a sample Kanban board where the tasks are divided into five phases: Pending Tasks (i.e., To Do Tasks), Requirement Analysis, Development, Testing, and Deployment. Within each phase, the tasks are again divided into Ongoing and Completed tasks. This visual organization helps to identify bottlenecks, and provides opportunities to address issues.

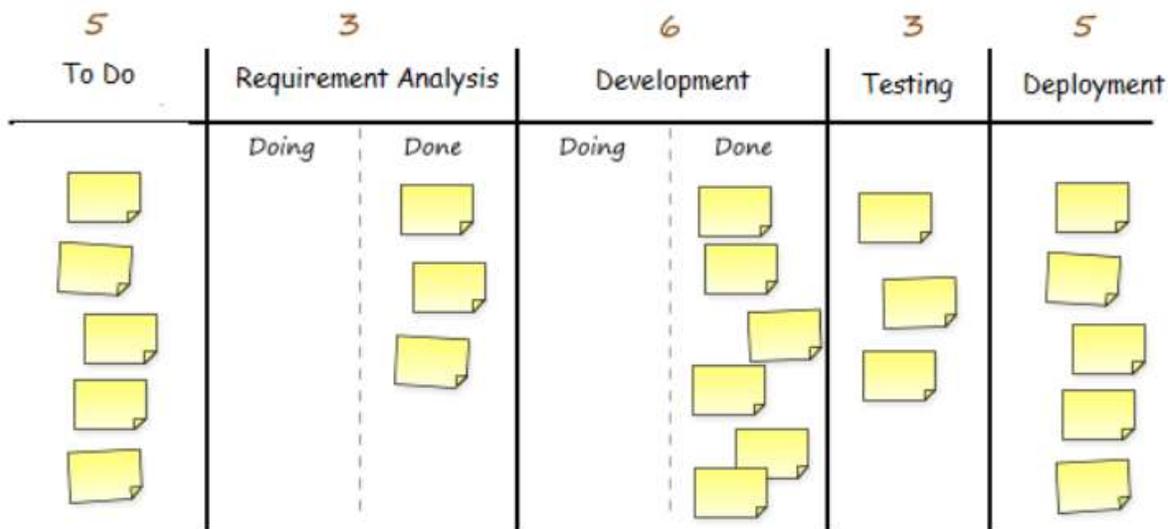


Figure 8.2: Sample Kanban Board

(Source: Zilicus Business Empowered, n.d.; South Carolina Manufacturing Partnership (SCMEP), 2017)

The Kanban approach is more suitable for projects that emphasize evolutionary change and customer focus. It is highly suited for interrupt-driven projects such as customer support centers. As such, Kanban (and not Scrum) is more appropriate for service-oriented projects. Since FDOT projects are usually large-scale, and not completely customer driven, Kanban may not be a suitable approach. However, FDOT is encouraged to consider Kanban for service-oriented projects.

8.1.4 Agile in the Private Sector

The private sector has adopted Agile framework since the 1990s, and this practice has been growing exponentially since 2001. Currently, about 80% of organizations have adopted at least some form of Agile methodologies (CC Pace Systems, Inc., 2014).

According to a survey of 173 companies conducted in December 2013, Agile was found to be successful in 64% of projects, challenged in 30%, and failed in 6% of projects (Scott, 2014). In contrast, the traditional approach was found to be successful in 49% of projects, challenged in 32%, and failed in 18% of projects. A project was considered “successful” if a solution was delivered, and the project’s success criteria was met within a range acceptable to the organization. A project was considered “challenged” if a solution was delivered, but the team did not fully meet all of the project’s success criteria within the acceptable range (for example, the quality was fine, the project was somewhat on time, but return-on-investment was too low). If the team did not deliver a solution, the project was considered as “failed” (Scott, 2014). Furthermore, in terms of effectiveness of the approach pertaining to time/schedule, budget or return on investment, stakeholder value, and product value, Agile methodologies were found to be significantly better compared to the traditional Waterfall approach (Scott, 2014).

VersionOne, Inc. (2015) conducted a state-of-the-practice review of Agile practices in the private sector by surveying a total of 3,925 companies around the world and from a variety of industries including software, financial services, professional services, health care, government, transportation, etc. The surveyed companies identified the following reasons for adopting Agile for their software development projects:

- Accelerate product delivery
- Enhance ability to manage changing priorities
- Increase productivity
- Enhance software quality
- Enhance delivery predictability
- Improve business/IT alignment
- Improve project visibility
- Reduce project risk
- Improve team morale
- Improve engineering discipline
- Reduce project cost
- Increase software maintainability
- Better manage distributed teams

8.1.4.1 Lessons Learned from the Private Sector

Ganesh and Thangasamy (2012) studied the challenges faced by an organization while transitioning from a Waterfall model to an Agile approach. The study was based on a real-time project carried out in a private IT company in India. The authors primarily focused on the

personnel management issues within the organization. Lessons learned gained from the study include:

- From the team members:
 - The team members should be willing to adapt or welcome change.
 - The team should have highly skilled people who are good at gathering requirements and executing them at ease.
 - The team members should be masters in all trades.
 - The team members should have a social movement.
 - The team members should understand the values and principles of Agile, rather than its practices.
 - The team should be self-organized.
 - The team members should take up collective responsibility, thereby should gain collective ownership.
 - The team members should be willing to do continuous integration, with continuous delivery and should be willing to adapt/change towards the continuous feedback from the customer end.

- From the Agile coach:
 - Slow motivation is required when transitioning from traditional to Agile approach.
 - Handholding or mentoring is required from an Agile coach. Proper guidance is mandatory at every initial stage.
 - Agile coach should act as a counselor and guide the team in a constructive way.
 - The coach should be responsible for increasing the rigor depending on the project needs.
 - Commitment of Agile coach needs to be very high during the initial weeks of transition.
 - It is the responsibility of the Agile coach to choose the measurements carefully, especially with respect to builds.
 - Changing the mindset of the team members and the project manager will be a challenge for the Agile coach until the project is completed, as it is very difficult to satisfy all the needs of a particular person.
 - The Agile coach should convene a meeting to have a discussion with the project managers who are willing to make a transition with a project manager who is already practicing Agile.

Deloitte, LLP (2016) has identified the following five key lessons learned from the private sector during transformation in the organizations. Although transformation, which usually requires a long-term culture change, is a broad concept. It could be observed in the context of project development as:

1. Define transformation widely but definitively for your organization.
2. Recognize that transformation brings greater complexity and demands on leaders.

3. Leaders need to be on a personal journey. They must learn how to lead without authority, and how to blend traditional management disciplines with experimentation and motivation.
4. Manage the program tightly, with well-designed phases and absolute clarity of accountability and decision rights.

8.1.5 Favorable and Unfavorable Conditions for Agile Development

Described by Rigby et al. (2016b), the following conditions are considered to be most favorable for adopting Agile framework in the project development process:

- Problems are complex.
- Solutions are unknown.
- Scope is not clearly defined and project requirements may change from the point of initial conception.
- Requirements will be more clear as the project progresses.
- Work can be split into small batches for rapid execution, which allows for iterations on an as-needed basis.
- Close collaboration with end users and rapid feedback from them are achievable.
- Incremental developments add value to the product for customers to test and use.
- Late changes can be managed without much trouble and cost.

On the other hand, Agile framework is not effective for the following conditions:

- Problems are not complex and can be solved sequentially.
- Requirements are clear at the onset and will remain stable.
- Constant collaboration is not possible due to customer unavailability.
- Solutions are clear from similar work done before.
- Detailed specifications and work plans can be predicted with full confidence.
- Customers cannot test the product until everything is complete.
- Late changes are expensive, or sometimes even impossible to implement.

Table 8.2 lists the technical, process, project management, and Agile enterprise-related impediments with adopting Agile methodologies.

Table 8.2: Impediments with Adopting Agile Methodologies
(Source: United States Government Accountability Office, 2012; CC Pace Systems, Inc., 2014)

Technical	Process	Project Management	Agile Enterprise
<ul style="list-style-type: none"> • Technical environments were difficult to establish and maintain. 	<ul style="list-style-type: none"> • Agencies had trouble committing staff. • Teams had difficulty managing iterative requirements. • Teams had difficulty collaborating closely. 	<ul style="list-style-type: none"> • Traditional status tracking does not align with Agile. • Compliance reviews were difficult to execute within an iteration time frame. • Traditional artifact reviews do not align with Agile. • Staff had difficulty committing to more timely and frequent input. 	<ul style="list-style-type: none"> • Timely adoption of new tools was difficult. • Agile guidance was not clear. • Federal reporting practices do not align with Agile. • Customers did not trust iterative solutions. • Teams had difficulty transitioning to self-directed work. • Traditional procurement practices may not support Agile projects.

8.2 Scrum Approach

Scrum is the most popular approach of Agile methodologies. The *Scrum Guide*, written by Ken Schwaber and Jeff Sutherland, who first introduced the Scrum concept, defines Scrum as a “framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value” (Schwaber & Sutherland, 2016). Scrum is not a technique that follows a series of sequential steps to build a product, rather it is a framework within which various techniques can be employed for organizing and managing work. Scrum offers an iterative, incremental approach to optimize predictability and manage risk. Scrum is lightweight, flexible, and easy to understand; however, it is difficult to master.

The main components of a Scrum framework are as follows:

- Scrum Team: Product Owner, Scrum Master, and Development Team
- Scrum Events: Sprint, Sprint Planning Meeting, Daily Scrum Meeting, Sprint Review Meeting, and Sprint Retrospective Meeting
- Scrum Artifacts: Product Backlog, Sprint Backlog, Increment, and Sprint Burndown Chart

Each component of the framework has specific functions critical to Scrum’s success. Figure 8.3 demonstrates the Scrum framework with the components and their interactions necessary to

complete the job. A detailed discussion of Scrum framework components is provided in the following sections.

8.2.1 Scrum Team

A Scrum team consists of a Product Owner, a Scrum Master, and a Development Team. Scrum teams are self-organizing as well as cross-functional. The roles of the Scrum team members are discussed in the following subsections.

8.2.1.1 Product Owner

A Product Owner performs two simultaneous functions - one is to coordinate with the stakeholders and customers to understand their needs and expectations, and another is to communicate to the development team what features to build and in which order to build them. In most cases the Product Owner should be a single person. This person is ultimately responsible for delivering value to the customers and to the business.

The Product Owner is the sole person to create and manage product backlog items. A product backlog is a prioritized list of simple items that must be done in order to build the product. The Product Owner must ensure that the product backlog is visible, transparent, and clear to all. Other than the Product Owner, team members cannot change the priority of items, remove items, or even add items in the product backlog. It is at the discretion of only the Product Owner to update the product backlog. In addition to collaborating with both customers and the development team, and managing the product backlog item, the Product Owner is also responsible for making good economic decisions, defining acceptance criteria for each product backlog item, and also ensuring that the criteria are met.

This position of a Product Owner does not typically exist in non-Scrum organizations. However, the responsibilities and authorities practiced by the Product Owner are similar to some existing roles in traditional organizations. Table 8.3 shows candidates for the Product Owner role for different types of development (Rubin, 2012).

Table 8.3: Product Owner Candidates for Different Types of Development

Development Type	Candidate Product Owner
Internal development	Representative from the business area benefiting from the solution
Commercial development	Typically a product manager or project manager
Outsourced development	Representative from the company paying for the solution and receiving the benefits
Component team (architectural development)	Typically a technical person who can best prioritize the backlog of technical items

The Agile Scrum Framework at a glance

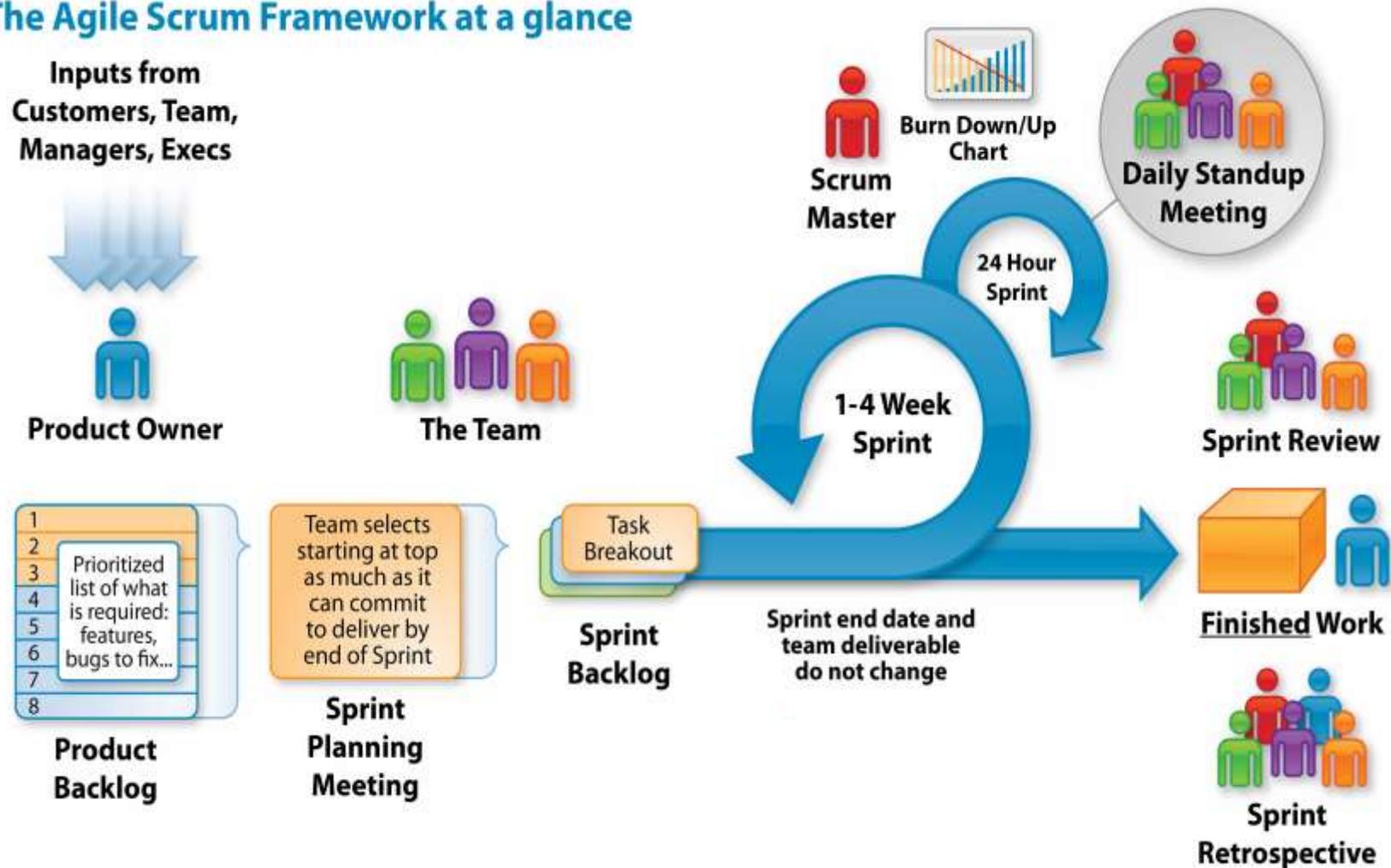


Figure 8.3: Scrum Framework
(Source: Neon Rain Interactive, 2010)

8.2.1.2 Development Team

A Scrum development team is built of professionals who follow the product backlog items and perform the work of delivering a product. The development team possesses the following characteristics (Schwaber and Sutherland, 2016):

- It is self-organizing, which indicates that only the members of the development team (not the Scrum Master or Product Owner) decide how to accomplish the tasks to deliver the product functionality.
- It is cross-functional, indicating that team members have all the skills required to build a product without depending on others outside the team.
- Scrum does not suggest giving titles to individual development team members regardless of the work being performed by a person; everyone in the team is a developer.
- Scrum does not allow for building any sub-teams in the development team regardless of particular areas that need to be addressed such as testing or business analysis.
- The development team as a whole, not a single member, is accountable for the completion of a task (product functionality) regardless of less-than-expected contributions by a team member or of major contributions by individual development team members who have special skills

The size of a development team should be optimal depending on the type of work the team is preparing to accomplish. The size should be small enough to maintain agility, yet large enough to be able to complete a work, with valuable inputs from each person involved in the development process. In general, it is suggested to build a development team consisting of three to nine members. A development team with fewer than three members may encounter skill constraints, resulting in failure to deliver a valuable outcome. On the other hand, a large body of members in a development team may introduce too much complexity for an empirical process to manage.

8.2.1.3 Scrum Master

A Scrum Master serves the Product Owner, the development team, and the organization to ensure that everyone on the team understands and follows Scrum theory, rules, and practices. This person emphasizes the need for clear and concise product backlog items, and encourages the team to organize different Scrum events in order to improve communications, remove impediments, and maintain agility. Table 8.4 shows the different roles of the Scrum Master.

Table 8.4: Roles of the Scrum Master

While Serving	Roles
Product Owner	<ul style="list-style-type: none">• Help the Product Owner understand product planning in an empirical environment• Help the Product Owner find the best technique for effective product backlog management• Ensure that the Product Owner works to arrange the product backlog items to maximize value

Table 8.4: Roles of the Scrum Master (continued)

While Serving	Roles
Development Team	<ul style="list-style-type: none"> • Coach the development team in self-organization and cross-functionality • Help the development team generate valuable product increments and ultimately create high-value products • Remove obstacles to the development team’s progress • Guide the development team to get to the next level of performance • Coach the development team in organizational environments where Scrum is not yet fully adopted and understood
Organization	<ul style="list-style-type: none"> • Lead and coach the organization in its Scrum adoption • Plan Scrum implementations within the organization • Help employees and stakeholders understand and enact Scrum and empirical product development • Take such actions that increase the productivity of the Scrum Team • Work with other Scrum Masters who are involved in other product developments in the organization to increase the effectiveness of the application of Scrum in the organization

8.2.2 Scrum Events

Scrum events are suggested to ensure regularity and facilitate transparency and inspection. Scrum events are usually short time-boxed events to minimize the duration of work for a longer or unspecified period. At the core of all Scrum events is the Sprint that manages the main activity of developing a product increment. Other events are centered around the Sprint, which include Sprint planning, daily Scrum, Sprint review, and Sprint retrospective. The following subsections describe each Scrum event.

8.2.2.1 Sprint

Scrum organizes work in iterations or cycles of fixed durations called Sprints. At the beginning of each Sprint, the Product Owner and the Development team discusses and agrees upon the work to be completed during a Sprint. Figure 8.4 demonstrates an example of how the product backlog items are selected and executed over multiple Sprints or iterations. Once established, no goal-altering changes in scope or staff are permitted during a Sprint. To certify that the work meets the Sprint goal, a definition of a “done” work is also agreed upon. Each Sprint focuses on adding features to a product.

Sprint is based on the concept of time-boxing, which means that the work to be completed in a Sprint has a time frame with specific start and end dates. The team must adhere to the time frame and complete the jobs agreed on by the Development team and the Product Owner at the beginning of each Sprint. Note that time-boxing is different from task scheduling. While a traditional task schedule allocates certain time to complete a task, time-boxing during each Sprint

ensures that only the work that is defined at the beginning of a Sprint is done, especially in the case of open-ended tasks.

Time-boxing provides the following benefits:

- It limits the amount of work-in-progress to avoid any unfinished job.
- It helps the team to prioritize and perform a small amount of work that has the most significant importance.
- It helps the team to make measurable progress by finishing and validating important pieces of work by a known date, i.e., the end of a Sprint.
- It helps identify and prioritize “must-have” features and avoid spending time on unnecessary meticulous details pertaining to “nice-to-have” features.
- It encourages team members to work diligently to complete the work on time.
- It improves predictability of the amount of work that can be completed in a short Sprint. In other words, it may be difficult to predict with great certainty exactly the work that can be completed in the next year; however, it is reasonable to predict the work that can be completed in the next short sprint.

Sprints usually have a short duration, typically from a week to a month. The benefits of keeping each Sprint short are manifold, as discussed below:

- It makes the planning easier as planning for a shorter period requires less effort.
- It allows the team to get fast feedback for early inspection and correction.
- It helps to minimize error of a large scale.
- It keeps the excitement among the members through gratification from early and frequent deliveries of a workable product.

In addition to a shorter time frame, Sprints must have consistent durations on a given development effort. The team should maintain consistency unless there is a compelling reason for not doing so. Situations, such as when the team at midway realizes that all the work specified under a Sprint cannot be done on time, should not be considered as an acceptable reason for extending the length of a Sprint. Rubin (2012) offered several situations as compelling reasons for deviating from a consistent duration of Sprints as follows:

- The team intending to move from four-week Sprints to two-week Sprints to get more frequent feedback.
- Annual holidays or end of fiscal year making it more practical to run a three-week Sprint rather than the two-week Sprint.
- The product release scheduling in one week makes a two-week Sprint wasteful.

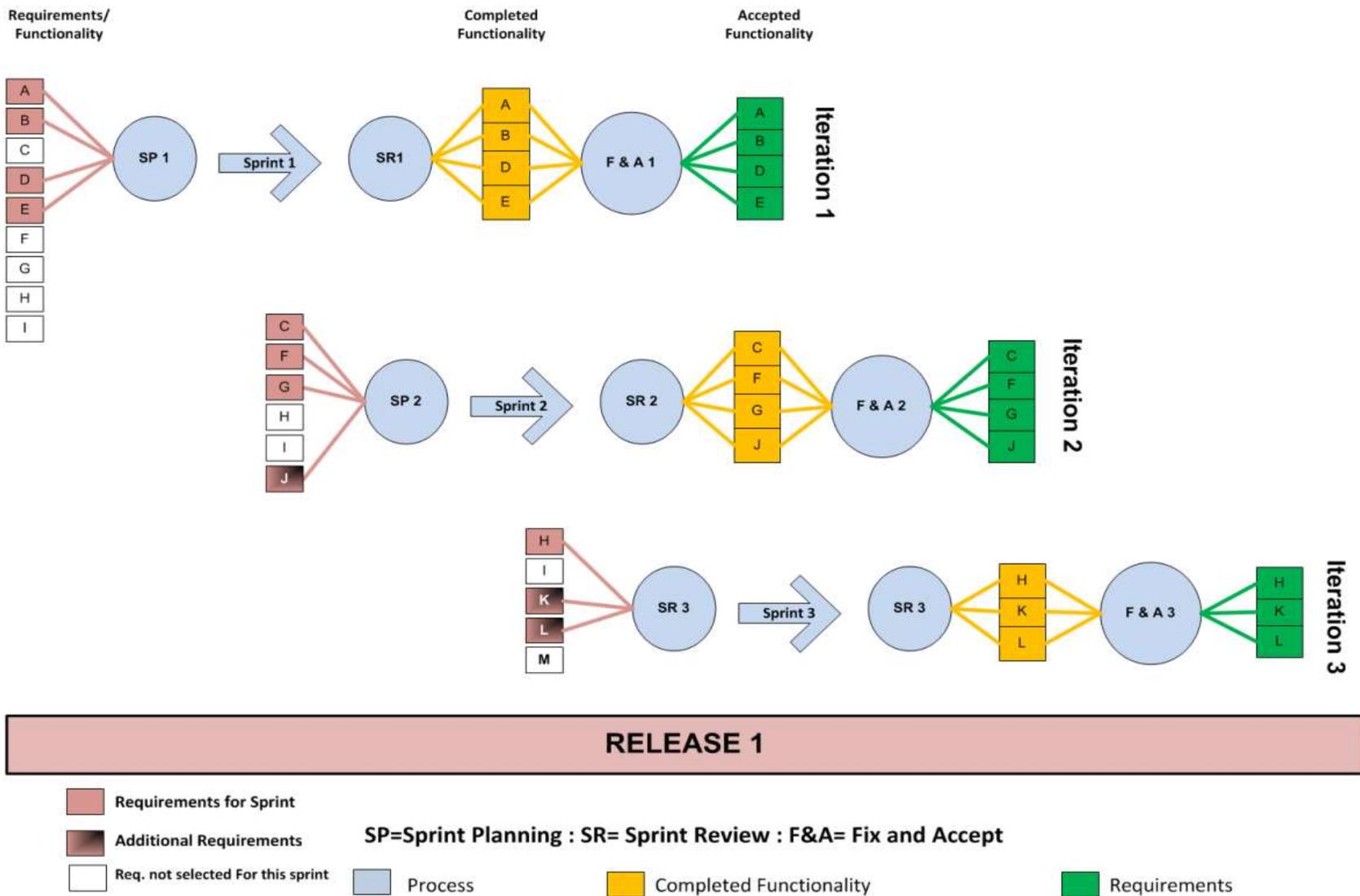


Figure 8.4: Sprint Workflow

(Source: de Leon & Petrina, 2016)

8.2.2.2 *Sprint Planning Meeting*

The Sprint planning meeting is a time-boxed event to discuss which product backlog items will be attempted to convert to a useable product in the upcoming Sprint. Every member of the Scrum team, including the Product Owner, the Scrum Master, and the Development team, participates in the meeting. The Scrum Master ensures that everyone understands the purpose of Sprint planning and the meeting is completed within the time-box. Two specific questions are discussed in the Sprint planning:

- What can be done in the upcoming Sprint?
- How will the work get done to achieve the Sprint goal?

The Product Owner discusses the product backlog items that are most important. The Development team selects from the product backlog the number of items that it can accomplish in the upcoming Sprint. After getting the Development team's input about what product backlog items it anticipates to deliver in the Sprint, the Scrum team establishes a Sprint goal. The Sprint goal is an objective that will be met within the Sprint through the implementation of the selected product backlog items. Setting a Sprint goal provides guidance to the Development team on why it is building the product increment.

Next, the Development team plans the work to accomplish the Sprint goal and build a useable product increment during the Sprint. The product backlog items selected for the Sprint and the plan for delivering them is called the Sprint backlog. The Development team usually plans for enough work that it believes it can accomplish in the upcoming Sprint.

8.2.2.3 *Daily Scrum Meeting*

The daily Scrum meeting is a time-boxed event of 15 minutes or less held by the Development team each day and ideally at the same time. Although the meeting is scheduled for a short period, its daily occurrence ensures improved communications, highlights working collaboratively, identifies and removes impediments, promotes quick decision-making, and improves the Development team's level of knowledge. The Scrum Master ensures that the Development team has the daily meeting; however, it is the responsibility of the Development team to conduct the daily Scrum. During the daily Scrum, each member of the Development team summarizes:

- what he/she did the previous day that helped the team meet the Sprint goal,
- what he/she is planning to do today to help the team meet the Sprint goal, and
- what impediments he/she is facing in meeting the Sprint goal.

After receiving updates from everyone, the Development team can measure how well the team is progressing toward accomplishing the Sprint goal. The Development team can also decide whether any modification to the plan for the upcoming day's work is required, and whether there are issues that need to be addressed. After the daily Scrum, the members of the Development team often immediately gather for detailed discussions, or to adapt or re-plan the remaining work of the Sprint. The daily Scrum is thus "an inspection, synchronization, and adaptive daily planning activity that helps a self-organizing team to do its job better" (Rubin, 2012).

8.2.2.4 Sprint Review Meeting

A Sprint review meeting is held at the end of each Sprint to exhibit the product increment to the Product Owner and stakeholders for inspection. The Sprint review meeting is the appropriate event for stakeholders, sponsors, customers, and interested members of other teams to attend. It provides the opportunity to inspect and adapt the product as it grows, and refines everyone's understanding about the product requirements. The meeting should feature a live demonstration, not a report presentation. It may last as long as four hours in the case of a one-month Sprint, or for shorter periods otherwise.

The Development team demonstrates the work completed in the Sprint and answers questions about the increment. The team also discusses what went smoothly during the Sprint, what specific problems occurred, and how those problems were solved. The Product Owner reviews the commitments made at the Sprint planning meeting and decides what product backlog items have been or have not been "Done". The entire group collaborates on what to do next to ensure that a valuable product increment is created during the next Sprints. The review includes how the marketplace or potential use of the product might have changed, along with the timeline, budget, and potential capabilities for the next anticipated release of the product.

8.2.2.5 Sprint Retrospective Meeting

The Sprint retrospective meeting occurs after the Sprint review and prior to the next Sprint planning. While the Sprint review is associated with inspect-and-adapt the product, the Sprint retrospective is associated with inspect-and-adapt the process. During the Sprint retrospective meeting, the Product Owner, the Scrum Master, and the Development team discuss together their actions and identify improvements needed for the next Sprint to optimize the team's performance.

To make the retrospective discussion successful, an environment of acceptance and security for each team member is essential. The organization should be ready to accept its internal limitations and work with a positive mind to resolve those limitations. The team members also should feel comfortable that the retrospection does not become hostile or a blame-game. The Scrum Master could adopt several techniques to facilitate retrospectives, including silent writing, timelines, and satisfaction histograms.

8.2.3 Scrum Artifacts

8.2.3.1 Product Backlog

The product backlog is an ordered list of desired product functionality, and is visible to all project participants. As aforementioned, the Product Owner maintains the product backlog, including its content, availability, and ordering. Similar to traditional ITS project development, the product backlog in Scrum itemizes the requirements. However, the requirements are not necessarily detailed and complete up front. In fact, the product backlog is updated continually

throughout the project as more solid information is available and requirements become clear. Therefore, a product backlog is essentially a living document.

The items in the product backlog, also known as product backlog items, are usually written in the form of user stories. User stories are structurally simple, and the Product Owner scripts the stories from a user's perspective. The Product Owner places himself or herself in the shoes of a user and writes down what feature he or she wants to see in an application, e.g., "As a user, I want to see a particular feature <feature name> in this app". Examples of this process are shown in Figure 8.5.

```
As a <customer> I want to <see the catalog of salable items>  
so that <I can order one of them>  
As an <administrator> I want <be able to disable accounts>  
As a <trainee> I must <answer all the questions>
```

Figure 8.5: Examples of User Story (Source: International Scrum Institute, 2016)

Writing an item or requirement in the form of a user story makes it easily understandable to both business and technical people. All the items in a product backlog are not at the same level of detail at the same time; usually, product backlog items at the top are more clear and detailed than those at the bottom. Because items are being added to the product backlog as the project progresses, the ordering of items is also not complete. It is suggested to prioritize those items that are expected to be implemented soon (i.e., in the next few sprints).

8.2.3.2 *Sprint Backlog*

The Sprint backlog is the set of product backlog items selected for the Sprint. The Development team decides which items to include in the Sprint backlog and plans the tasks that need to be accomplished to deliver a product increment incorporating those items. The tasks can be divided into the following three groups: (1) tasks not started, (2) tasks in progress, and (3) tasks completed. Sprint backlog and a plan for delivering the increment is often represented on a physical task board to make it transparent for all involved in the Scrum team (see Figure 8.6). No changes in the Sprint backlog is acceptable, as it will make the Sprint goal unstable and difficult to achieve. However, the Development team can add or modify the tasks that have not yet been completed to meet the fixed Sprint goal. The Scrum backlog is the reference point for the daily Scrum meeting.

8.2.3.3 *Increment*

The Increment is the sum of all the product backlog items that are "Done" during a Sprint. An increment is "Done" when it meets the acceptance criteria set at the beginning of the Sprint. An

increment adds value to the product. It must be in useable condition regardless of whether the Product Owner wants to release it.

Committed Backlog Items	Tasks Not Started	Tasks In Progress	Tasks Completed
	  		 
	  		
	     		
			

Figure 8.6: Sprint Backlog Tasks (Source: James & Walter, 2010)

8.2.3.4 Sprint Burndown Chart

The Sprint burndown chart is used to track the progress of a Sprint toward achieving the Sprint goal. It provides an estimate of remaining task hours within the Sprint, which allows the team to take action if needed to speed-up the remaining activities. Figure 8.7 demonstrates a Sprint burndown chart. The horizontal axis of the chart shows the day of the Sprint, whereas the vertical axis indicates the amount of work remaining. The remaining work is usually represented by story points.

The Scrum Master is responsible for updating the burndown chart. It is updated after each Daily Scrum meeting. The variations are often exploited to invite management intervention, minimizing the effectiveness of the team and hampering the original intention of facilitating self-organization of the team. It is therefore suggested that the Scrum Master should consider discontinuing to use the Sprint burndown chart if it becomes an impediment to team self-organization.

8.2.4 Scrum in Distributed and Large Projects

This section describes how to manage and organize work within the Scrum framework for large-scale projects. It is often difficult for a single Scrum team to realize large projects within a fixed

short amount of time. One solution is to increase the number of teams and distribute the work to multiple teams. While distributing the work, the teams can be formed as either component teams or feature teams. However, this approach will require integration of all of the efforts of the independent teams.

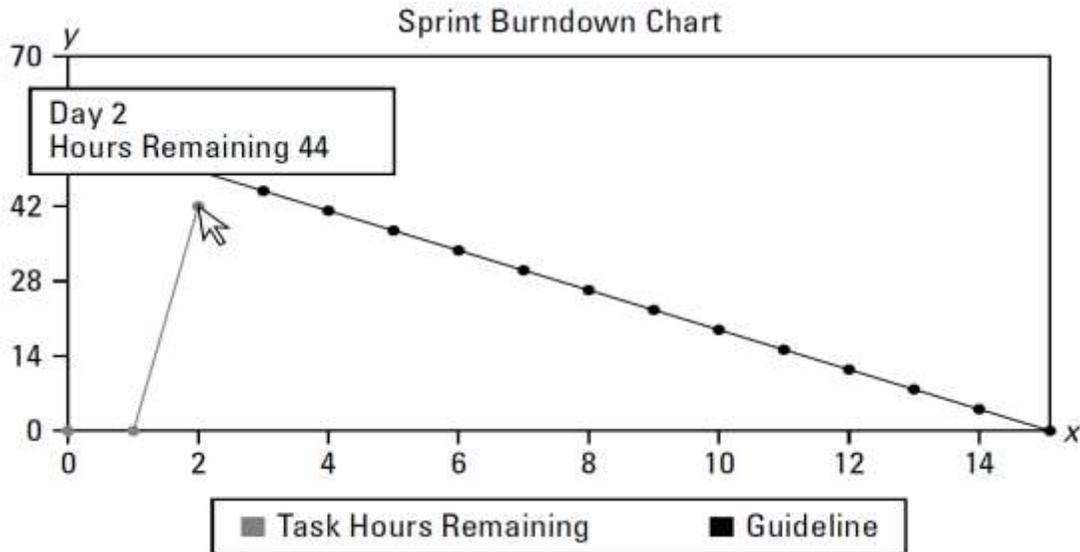


Figure 8.7: Sprint Burndown Chart (Source: Moreira et al., 2010)

8.2.4.1 Component Teams

Component teams are formed to build specific components of a product feature instead of the entire product feature. A component team is responsible for implementing similar types of work across multiple Sprints. Usually, members who have similar skills and expertise in a particular subject-matter belong to a single component team. Figure 8.8 demonstrates the distribution of work into different components teams. Note that the integration of work between the component teams needs to occur on a regular basis. One major challenge with integration arises when one team depends on results that are not yet available from another team. This is known as "Pipelining", and the teams should work to avoid these situations.

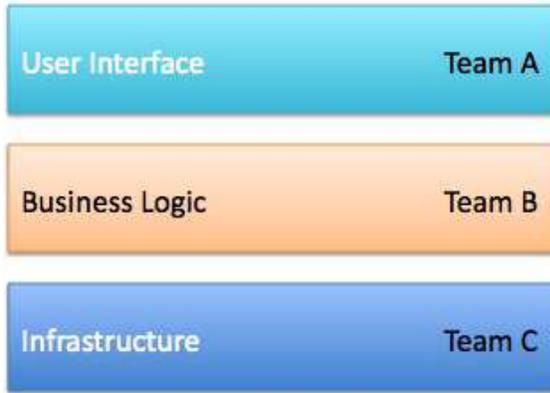


Figure 8.8: Scrum Component Teams
(Source: International Scrum Institute, 2016)

8.2.4.2 Feature Teams

Feature teams, on the other hand, are cross-functional and cross-component teams that work toward implementing a single feature as represented in the product backlog. Feature teams are formed with interdisciplinary members, offering an opportunity to share system-wide knowledge within the team, thus making the integration easier. Each feature team can run autonomously. The caveat is that ensuring consistency of the system architecture and having individuals with enough knowledge in each team, is difficult. Figure 8.9 demonstrates an example of how different feature teams work, where each feature team works on a single user story consisting of a variety of components.

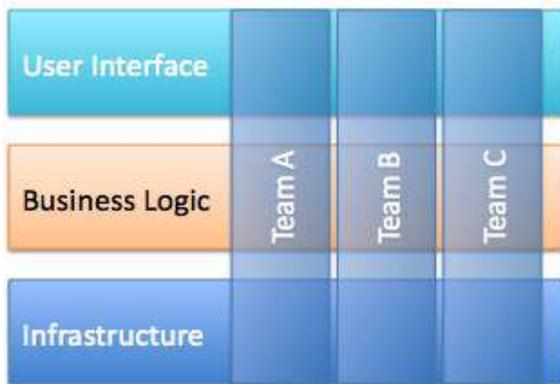


Figure 8.9: Scrum Feature Teams
(Source: International Scrum Institute, 2016)

8.2.4.3 Component and Feature Teams

Oftentimes, component teams and feature teams can be combined depending on the features to be developed and the availability and skills of team members developing those features. Figure 8.10 illustrates how two feature teams and one component team are combined to accomplish the project task.

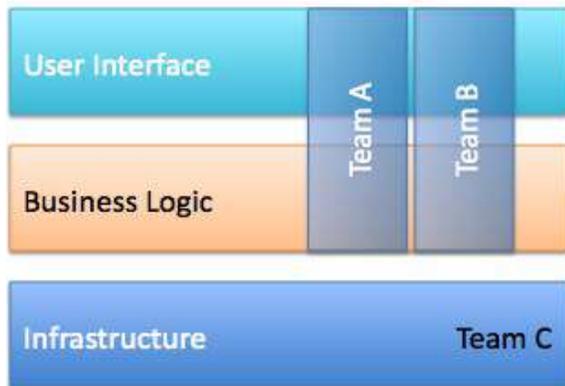


Figure 8.10: Combination of Component and Feature Teams
(Source: International Scrum Institute, 2016)

8.2.4.4 Number and Location of Multiple Teams

According to the International Scrum Institute (2016), the following rules should be followed to determine the optimal number and location of teams:

- Start with a single team for one or two Sprints initially
- Add a small number of other teams
- Closely observe whether the teams have stabilized
- Increase the number of teams in small steps

In general, the number of teams should not grow too quickly, although should be just enough to achieve the product functionality. The teams can be formed to work at the same location or over multiple locations. Communication between the teams, either co-located or distributed, is a key criterion for successful implementation of the Scrum goal. Each member of the distributed teams should have access to video-conferencing or tele-conferencing tools to ensure proper communication.

8.2.4.5 Product Owner in Large Projects

A close communication between the Product Owner and the team is vital for the project's success. In the case of multiple teams in multiple locations, a single Product Owner may be strained for time while performing duties required for the Scrum team in addition to regular job duties. Therefore, it is often encouraged (although not required) to have multiple Product Owners

to ensure that a team can always interact with a Product Owner. All Product Owners should work following a single product backlog. One of the Product Owners should have the role of the ‘Chief Product Owner’ who will be responsible to oversee that the product is developed in a coordinated fashion (see Figure 8.11).

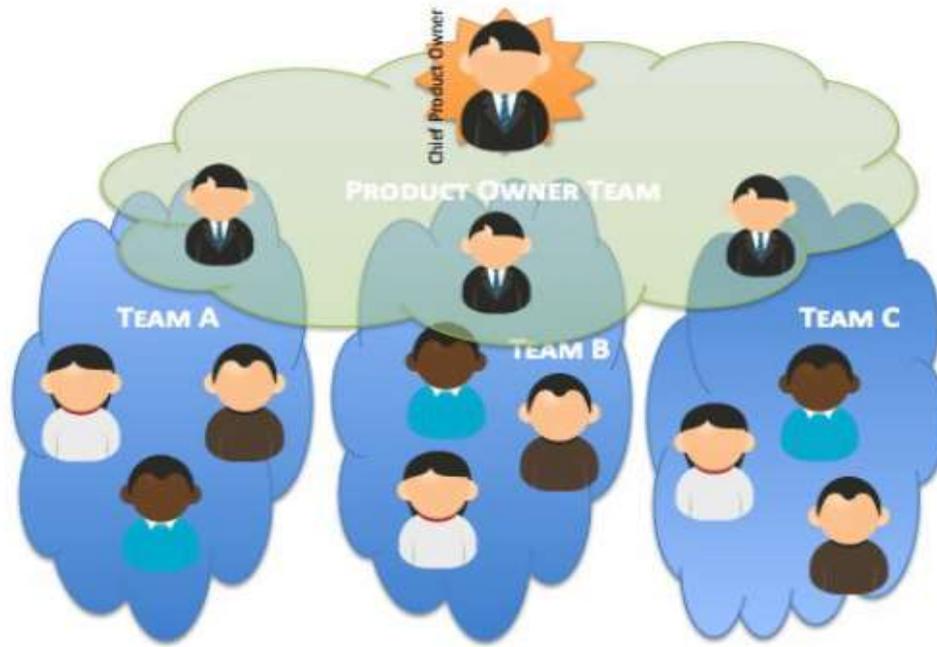


Figure 8.11: Product Owner Teams in Large Projects
(Source: International Scrum Institute, 2016)

8.2.4.6 Scrum Master in Large Projects

In a large project, the role of the Scrum Master is even more important as large projects with multiple teams are likely to encounter more impediments. It is the responsibility of the Scrum Master to be attentive and take action to remove obstacles. For an efficient operation, the Scrum Master should be located at the same location as the team. Ideally, there should always be a single Scrum Master; however, a local Scrum Master may be present in teams spread over multiple locations.

8.3 Sample Project Using Agile Methodologies

8.3.1 Project Background

Incident management is one focus area of TSM&O, with the strategy goal of minimizing incident response and clearance time on freeways and arterial roadways. Several districts, including D4 and D6 have been implementing strategies that focus on enhancing incident management.

One way to minimize incident response and clearance time is to streamline the process used by the Traffic Management Centers (TMCs) to detect, verify, respond, and clear incidents. Although districts use different procedures to perform these operations, the procedures are quite similar. The general steps performed by TMC staff include:

- 1. Incident Identification:** Incidents are identified using various sources, including the Florida Highway Patrol (FHP), local law enforcement officials, Road Rangers, TMC staff from CCTV cameras, and motorists reporting, using smartphone applications such as *Waze*. Some of these reporting methods can be more easily verified compared to others. For example, incidents reported through the *Waze* smartphone application often do not have the exact location coordinates, requiring the use of other methods to verify the reported incident location and severity.
- 2. Incident Documentation:** Once an incident is identified, an Incident Report is created. The Incident Report includes essential information pertaining to the incident such as, an identification number, type, severity, time reported, reporting person/agency, vehicle information, and roadway and traffic conditions at location site (shoulder blocked, number of lanes blocked, etc.), etc.
- 3. Incident Verification:** Once an incident is identified, it has to be verified by a secondary source. For example, an incident reported via *Waze* may be verified by TMC staff using CCTV cameras or by Road Rangers, etc.
- 4. Information Dissemination to Agencies:** Depending on the severity of an incident, other applicable agencies must be informed. These agencies include, among others, emergency responders, the Fire Department, towing agencies, FDOT Maintenance Asset Office, Office of Wildlife Service, and Construction Office.
- 5. Information Dissemination to Public:** An essential component of incident management is informing the public about the incident, along with details such as time, type, duration, and severity. As such, the TMC staff are responsible for posting the information on the Dynamic Message Signs (DMS), 511 website, etc.
- 6. Incident Response Strategy Documentation:** Once all the relevant agencies are notified, the next steps depend on incident severity. The TMC tracks and records the time first responders arrive, the time when lanes are reopened to traffic, the time the incident is cleared, and the time traffic conditions return to normal conditions.

In addition to the aforementioned steps, during the incident management process, the following situations also may be considered:

- **Secondary Crash Identification:** Secondary crashes have increasingly been recognized as a major problem on freeway traffic operations, leading to reduced capacity, extra traffic delays, and increased fuel consumption and emissions. Recognizing the potential for secondary crashes in real time can help incident responders. Pre-defined spatio-

temporal factors are used to identify secondary crashes (e.g., 2 miles, 120 minutes upstream of the incident). They can also be identified by dynamic methods that take into account the traffic conditions in real-time. Identifying potential secondary crashes that occur within the spatio-temporal boundaries of the primary incident is considered an active traffic management (ATM) strategy that improves traffic conditions by reducing delay and congestion.

- **Incident Management Strategies on Arterials:** Incidents on arterials are also a major concern for TSM&O staff. Monitoring and clearing incidents on arterials is considered an enhancement to the existing ATM strategies. Incident management on arterials comes with its own set of challenges in terms of incident detection, verification, and clearance procedures. Nevertheless, Districts have been considering incorporating these strategies to improve traffic conditions on the arterial network.

8.3.2 Project Objective

The primary objective of the project is to develop a process to streamline incident response procedures for better incident management on freeways. More specifically, a web-based data repository and database management system is to be developed to help facilitate the following six incident management steps discussed in the previous section, which are:

1. Incident Identification
2. Incident Documentation
3. Incident Verification
4. Information Dissemination to Agencies
5. Information Dissemination to Public
6. Incident Response Strategy Documentation

8.3.3 Traditional Process

The FDOT's existing TSM&O project development process includes the following broad phases:

- Project Concept and Programming (Feasibility Study/concept exploration)
- Planning (ConOps and SEMP)
- Preliminary Design (component level design)
- Final Plans, Final Design, and Specifications (software/hardware development)
- Construction (field installation and unit/device testing)
- Operations and Maintenance (system deployment, verification and validation/changes and upgrades)

The traditional Waterfall project development model is usually adopted for the Preliminary Design phase and beyond. The Waterfall model (discussed in Section 7.3.1) includes the following steps:

- Requirements Analysis
- Design
- Code
- Integration
- Test
- Deploy

To develop a web-based data repository and database management system to incorporate all six incident management steps using the Waterfall approach, data will be gathered and analyzed during the Requirements Analysis phase. Once the system requirements are identified, it could take approximately 18 months to design, code, and integrate, another six months to test the system, and yet another two to three months to complete deployment. The entire process, from initial conception to completion, is expected to span just over two years. If this approach is used, FDOT may not be able to use the final product (i.e., web-based system) due to changing technology.

8.3.4 Scrum Approach

Unlike the traditional process, Scrum is a framework within which various techniques can be employed for organizing and managing work. Scrum offers an iterative, incremental approach to optimize predictability and manage risk.

For this project, if the Scrum framework is adopted instead of the traditional Waterfall approach, FDOT could use the first version of the product with limited capabilities within two to three months of the initial conception. For example, the first version that includes multiple sprints could focus on creating the *Data Entry Form* for TMC staff to input the incident information. Once the *Form* is created, the system will be available for use by TMC staff. Although the functionalities of the first version of the system are limited, the FDOT Project Manager will also have the opportunity to use it, and suggest changes. Note that these changes are easier to incorporate since the system is still being developed.

The main components of a Scrum framework are as follows:

- Scrum Team: Product Owner, Scrum Master, and Development Team
- Scrum Events: Sprint, Sprint Planning Meeting, Daily Scrum Meeting, Sprint Review Meeting, and Sprint Retrospective Meeting
- Scrum Artifacts: Product Backlog, Sprint Backlog, Increment, and Sprint Burndown Chart

In this scenario, the TSM&O Project Manager at FDOT would be the Product Owner. The consultant working on developing the product would be the Development Team. The Scrum Master would be the liaison between the Product Owner (i.e., FDOT) and the Development Team (i.e., consultant). Sprints could be two weeks in duration. Within each Sprint, the following meetings will be conducted:

- **Sprint Planning Meeting:** Conducted between the Product Owner and the Development Team. The Product Owner first lists all items that need to be done. The Product Owner and the Development Team will meet and decide what the Development Team can do in the next sprint which will start the day after the meeting.
- **Daily Scrum Meeting:** A daily project update meeting will be conducted within the Development Team; the Product Owner can attend if needed.
- **Sprint Review Meeting:** This meeting focuses on the product that is being developed; how the development goes, whether the sprint goal is fulfilled or not.
- **Sprint Retrospective Meeting:** This meeting focuses on the difficulties faced by the Development Team, and how to improve them. It is conducted at the end of each sprint, on an as-needed basis. The meeting also focuses on how the Development Team performed, and any other problems that arise during the sprint.

The Scrum Artifacts are discussed in the following paragraphs using a simple example. Figure 8.12 demonstrates an example of how the product backlog items are selected and executed over multiple Sprints or iterations. Product Backlog items are the items that are embedded in the system. For example, the *Form* created to record incident information could include the items A through M listed in Figure 8.12. Sprint Backlog is the subset of Product Backlog; it includes items selected during the sprint planning meeting to do during the next sprint. Table 8.5 lists the Sprint backlog tasks in each sprint, which include the committed backlog items, tasks not started, tasks in progress, and tasks completed. Increment in each sprint includes all the items that are completed during that sprint. Finally, the Sprint Burndown Chart shows the progress of the project within the sprint (e.g., number of hours spent).

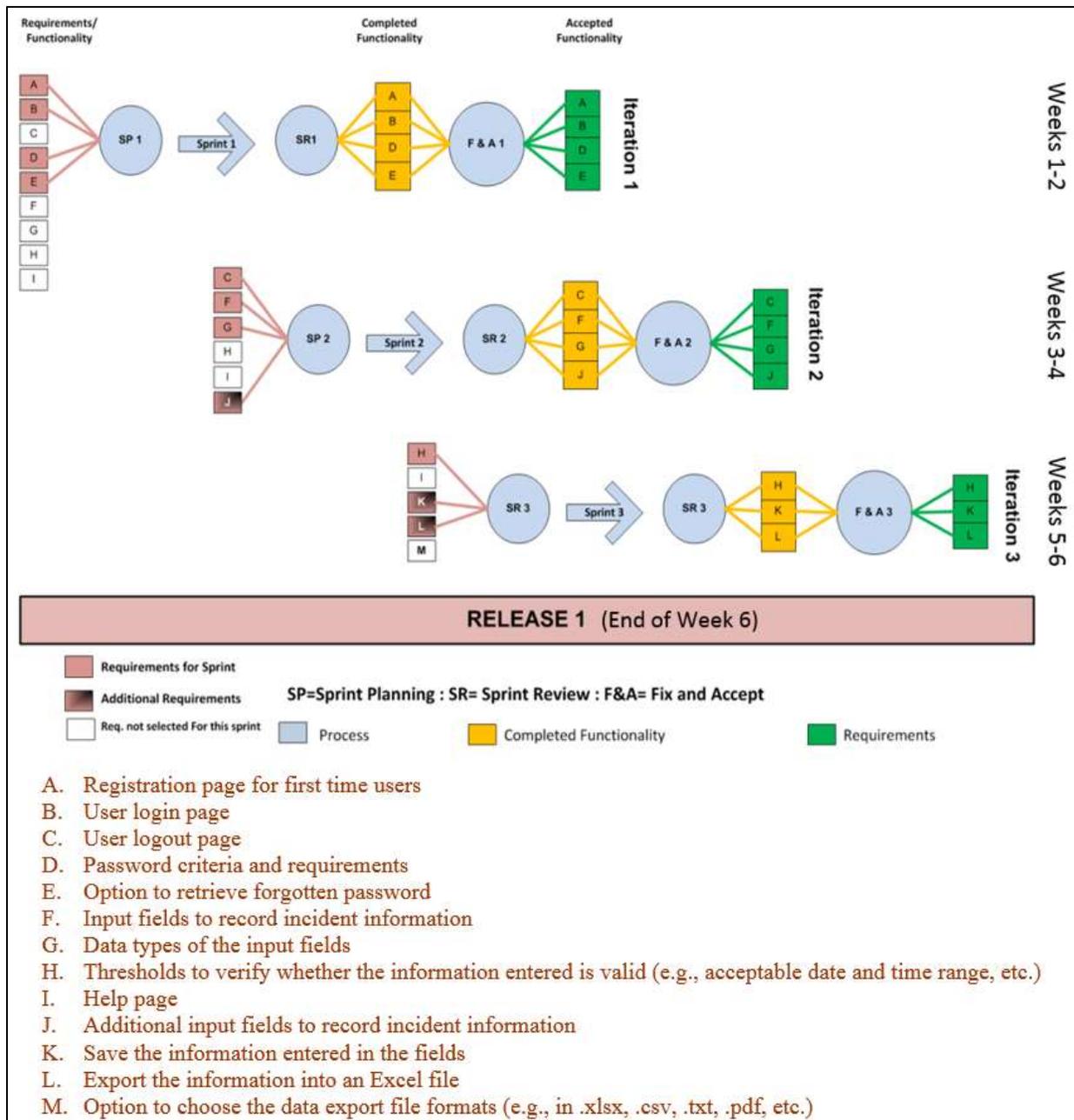


Figure 8.12: Sprint Workflow for the First Release
(Adapted from de Leon and Petrina, 2016)

Table 8.5: Sprint Backlog Tasks

Sprint No.	Committed Backlog Items	Tasks Not Started	Tasks in Progress	Tasks Completed
1	<ul style="list-style-type: none"> • Registration page for first time users • User login page • User logout page • Password criteria and requirements • Option to retrieve forgotten password • Input fields to record incident information • Data types of the input fields • Thresholds to verify whether the information entered is valid • Help page 	<ul style="list-style-type: none"> • User logout page • Input fields to record incident information • Data types of the input fields • Thresholds to verify whether the information entered is valid • Help page 		<ul style="list-style-type: none"> • Registration page for first time users • User login page • Password criteria and requirements • Option to retrieve forgotten password
2	<ul style="list-style-type: none"> • User logout page • Input fields to record incident information • Data types of the input fields • Thresholds to verify whether the information entered is valid • Help page • Additional input fields to record incident information 	<ul style="list-style-type: none"> • Thresholds to verify whether the information entered is valid • Help page 		<ul style="list-style-type: none"> • User logout page • Input fields to record incident information • Data types of the input fields • Add additional input fields to record incident information
3	<ul style="list-style-type: none"> • Thresholds to verify whether the information entered is valid • Help page • Save the information entered in the fields • Export the information into an Excel file • Option to choose the data export file formats 	<ul style="list-style-type: none"> • Help page • Option to choose the data export file formats 		<ul style="list-style-type: none"> • Thresholds to verify whether the information entered is valid • Save the information entered in the fields • Export the information into an Excel file

For large-scale projects, such as this sample project, it is often difficult for a single Scrum team to fully realize the project within a fixed, short amount of time. One solution is to increase the number of teams, and distribute the work to multiple teams. While distributing the work, the teams can be formed as either component teams or feature teams.

Component teams are formed to build specific components of a product feature instead of the entire product feature. A component team is responsible for implementing similar types of work across multiple Sprints. Usually, members who have similar skills and expertise in a particular subject-matter belong to a single component team.

Feature teams, on the other hand, are cross-functional and cross-component teams that work toward implementing a single feature as represented in the product backlog. Feature teams are formed with interdisciplinary members, offering an opportunity to share system-wide knowledge within the team and making the integration easier.

In this project, the three major component teams at the TMC would be: the User Interface Team, the Data Integration and Processing Team, and the Hardware Setup Team. Figure 8.13 demonstrates an example of how different feature teams work, where each feature team works on a single user story consisting of a variety of components.

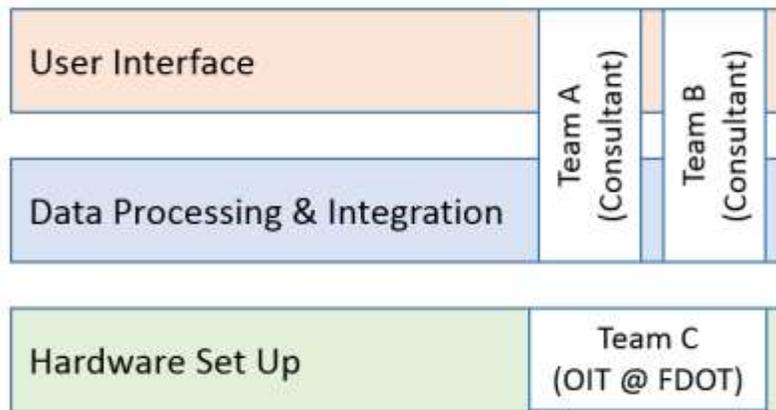


Figure 8.13: Combination of Component and Feature Teams

8.3.5 Reflection

Project requirements are set in the traditional Waterfall model. The final product, built to the original specifications, oftentimes does not serve all the needs of the organization. Therefore, a follow-up project to do enhancements is often needed. In contrast, when a pure Agile approach is adopted, the solution evolves with frequent iterations. Moreover, Agile methods allow the end users to see and use the product very quickly. However, in this approach, the original software framework may be inappropriate for the final product. The final product may not meet the performance requirements, or may be poorly designed, and have spaghetti code that is inefficient. Therefore, a proper balance between the two approaches is most suitable, especially for large and complex projects. The balance is typically based on the details provided in the functional requirements versus the requirements that are to be provided in the detailed design phase of the project.

8.4 Embracing Agile Principles

8.4.1 Applications of Agile in Government Organizations

Public agencies typically have strict project processes and requirements. This can make adopting the Agile philosophy challenging. The Agile approach emphasizes fast and consistent progress, and requires constant and effective communication. The decision-making process in public agencies may hinder this approach. Nonetheless, Agile practices can be adapted to manage projects in the public sector (LaBrosse & Alpine, n.d.). Using Agile for government projects is not uncommon; for example, Washington State, Texas, and Tennessee have used Agile methodologies for select projects.

The Office of Chief Information Officer (OCIO) in the State of Washington has been using Agile principles for IT projects for several years. The Office used the Scrum approach to build a Business One-Stop portal to provide small businesses with a “one-stop” solution for licensing, regulatory assistance, and other related information. The primary motivation for using Scrum was to reduce time, cost, and frustration related to compliance with state regulations, as well as, to gain faster feedback to ensure that the development team remain focused on the highest-priority items that add tangible value at the end of each Sprint (OCIO, 2013).

The Texas Department of Public Safety (DPS) and the Texas government (Texas.gov) used Agile methodology to create a tool for the state’s vehicle inspection service. The project team followed the Scrum method with a two-week Sprint period. After each Sprint, the teams from Texas DPS and Texas.gov met to discuss their developments and make necessary adjustments to ensure that the project remained on track. The project duration was shorter, and the cost was lower, compared to previous implementations. In fact, the tool was developed in only nine months, half the time required to build the previous tool (18 months). The state also decided to expand functionality for additional services and departments, all using Agile development (Wood, 2013).

Tennessee Department of Transportation (TDOT) observed the success of Agile methodology in a pilot project that dealt with building a simple application. It took the Scrum team only 12 weeks to get the application into production after incorporating feedback from others. Following this initial success, TDOT has gradually made its IT department into an Agile organization by investing in developing people with knowledge of Agile practices (Kirk and Holden, 2016).

8.4.2 Applications of Agile in FDOT

FDOT has been using Agile methods, although informally, in their project development processes. For example, enhancements to the *FL511.com* system were performed using iterative process. FDOT believed that it was beneficial to improve the product rather than to create and recreate documentation. On the other hand, Maintenance Information Management System (MIMS) was originally developed using the traditional Waterfall approach. However, enhancements to the MIMS were effectively accomplished by using an Agile approach.

For the development of the Active Arterial Management (AAM) Dashboard and Integrated Corridor Management System (ICMS), D5 attempted to use the agile methodology. Both projects used lump sum as the method of compensation. The agile method was selected by the contractor as a cost savings method. The AAM dashboard is now complete, with three sprints used in the development. Minor changes were made during the sprints to improve functionality of the system. No additional compensation was required for the minor tweaks as agile process was used. However, the interim deliverables did not provide standalone functionality. Overall the project was completed on time and within budget.

The ICMS is currently under acquisition. The agile methodology was selected by the vendor to eliminate the risk of a large complex system integrating over 40 data sources. The sprints are being used to ingest a handful of data sources at a time, and then to display the resulting widgets on an operator dashboard. This sequential approach is being used to identify issues prior to unit testing.

Since the adoption of Agile principles is not considered mandatory, a change in FDOT policy to consider adopting Agile methods in the project development process for TSM&O/ITS projects, to the extent possible, is beneficial.

8.4.3 Agile Approach for TSM&O/ITS Projects

TSM&O/ITS software programs are either developed in-house or acquired from the marketplace. Agile principles and Scrum methods discussed in previous sections can be established and followed for in-house developments with relative ease. Software packages or programs available in the marketplace are commonly known as Commercial Off-The-Shelf (COTS) products. COTS refers to software that is “commercially made and available for sale, lease, or license to the general public” (Gansler and William, 2008) with little or no modifications demanded by the procuring agency. COTS products are oftentimes preferred to in-house developments because of their rapid availability, low cost, and low exposure to risk. COTS-based development, also called COTS selection, involves looking for and acquiring software products, customizing and integrating them, writing the contracts, and constantly evaluating the marketplace to update the current packages with new releases (Navarrete et al., 2005). This section discusses how Agile methods and principles can be applied to COTS-based development.

Of the 12 Agile principles discussed in Section 8.1.2, Navarrete et al. (2005) describe the following four principles that are not applicable to COTS-based development:

1. Satisfy customers through early and continuous delivery of valuable work/product.
2. Convey information to and within a development team through face-to-face conversation.
3. Measure progress by the amount of completed work.
4. Build self-organizing teams to have the best outcome in plans, requirements, and designs.

The remaining eight Agile principles, in the context of COTS-based development, are discussed below:

1. *Welcome changing requirements at any stage of a project*: COTS software products available in the marketplace are vast and offer a great deal of information, often realized as the selection process progresses. Product information is generally undergoing constant evaluation, and is changed as new technology emerges into the market. Therefore, the requirements for COTS-based systems have to be flexible in order to capture the current needs of the marketplace.
2. *Deliver working product frequently, with a preference to the shorter timescale*: To apply this principle to processes, such as marketplace exploration, requirements analysis, COTS evaluation, etc., COTS-based development should be iteration-based. In each iteration, progress is made by either selecting better or more processes.
3. *Ensure regular collaboration between the project team and business people*: While business people and developers are the two main roles in a typical in-house software development project, the COTS-based development has a third role, the COTS vendor (or supplier). It is often feasible to include the vendor in the development team. Understandably, the inclusion of the vendor depends on various factors such as the type of COTS products and/or vendors, and the budget of the project, etc. By being part of the team, the vendor can learn about the project and the integration potential of the product, while also assisting the organization that delivers the system (i.e., system provider) to customize the COTS products. Depending on the nature of the process, other roles may also be included in the team. For example, final COTS selection involves writing of licenses and contracts for the selected components. An attorney or person with expertise in current regulations and laws is, therefore, required on the team to make the selection process a true team effort.
4. *Build projects around motivated individuals*: The COTS-based development involves new responsibilities and new roles; so, it must be ensured that the team members are capable and have sufficient knowledge to select and evaluate the appropriate components.
5. *Maintain a constant pace for sustainable work progress*: In COTS-based development, selection of product components must continue at a constant pace, including iterative evaluations and constant feedback.
6. *Pay continuous attention to technical excellence and good design for enhancing agility*: The COTS products must be of high quality in order for them to be selected as the final product.
7. *Maintain simplicity, the art of maximizing the amount of work not done*: Because COTS components are likely to become quickly obsolete, the key is to maintain simplicity such that the appropriate elements are evaluated, i.e., “think on the future just when this future may happen” (Navarrete et al., 2005).
8. *Retrospect previous steps at regular intervals to tune and adjust the team’s behavior to become more effective*: This principle is crucial in COTS-based development as it requires

more experimentation and increased knowledge. The use of repositories may help the system provider to tune and adjust its behavior frequently.

8.4.4 Organizational Transition to Agile

Oftentimes, projects developed by government agencies/organizations have obsolete requirements, high cost of change, are over-customized, and place minimal focus on users. This occurs primarily for three reasons: (a) complex policies with numerous dependencies; (b) rapidly evolving technologies and priorities; and (c) government processes are typically slower and unresponsive (Myer and Yoxall, 2011). Organizational transition from the traditional Waterfall approach to Agile methodologies is therefore necessary to help complete projects that meet the requirements, and are on-time and on-budget. This section focuses on the challenges, strategies, and the recommended action framework for government agencies to adopt Agile principles.

8.4.4.1 Agile Transition Challenges

Agencies that are interested in Agile have been using traditional methods for several decades. Moving to Agile methodologies may require significant restructuring of the organization, and changing the perspectives of the staff. The major barriers with transitioning to Agile are summarized in Table 8.6, and discussed below (Gandomani et al., 2013).

Table 8.6: Failure Factors
(Source: Chow and Cao, 2008)

Dimension	Factor
Organizational	<ul style="list-style-type: none"> • Lack of executive sponsorship • Lack of management commitment • Organizational culture too traditional • Organizational culture too political • Organizational size too large • Lack of Agile logistical arrangements
People	<ul style="list-style-type: none"> • Lack of necessary skill-set • Lack of project management competence • Lack of team work • Resistance from groups or individuals • Bad customer relationships
Process	<ul style="list-style-type: none"> • Ill-defined project scope • Ill-defined project requirements • Ill-defined project planning • Lack of Agile progress tracking mechanism • Lack of Agile progress tracking mechanism • Lack of customer presence
Technical	<ul style="list-style-type: none"> • Lack of complete set of correct Agile practices • Unsuitability of technology and tools

- Organizational culture-related: Transforming from traditional to Agile approaches require changing the management style from “command and control” to “leadership and collaboration” (Yang et al., 2009). Moreover, the role of project manager “should be altered from planner and controller to director and coordinator” (Moe et al., 2009; Monteiro et al., 2011). However, changing the mind set of project managers may take time and require mentoring (Pikkarainen et al., 2012). In addition, Agile approach, in some respects, changes the power balance in an organization from managers to individuals, which may present considerable challenges for some managers.

Another challenge with adopting Agile is with respect to documentation. While the traditional methods perform knowledge management using thorough documentation, documentation is limited in Agile methods, and knowledge often resides with the development team members.

- Human aspects-related: The process of transitioning from traditional approach to Agile approach is people-centered. Human aspects are therefore considered to be a major impediment to Agile adoption. Some of the human impediments to change include: resistance to change, cultural issues, lack of knowledge, wrong mindset, lack of collaboration, and becoming worried, indifferent, or have unrealistic expectations about the transition process.
- Process-related: Unlike traditional methods where processes are based on defined activities and measurements, Agile processes are based on uncertain activities that support rapid development and high quality production. Therefore, establishing adequate and documented measuring tools in Agile methodologies can be challenging. Likewise, changing process models from the traditional life cycle model to an Agile model that is evolutionary and iterative can also be a challenge. This change has significant influence on strategies, tools, techniques, and roles of staff members.
- Technology-related: Using non-flexible tools and hardware is a barrier in moving to Agile. Companies are encouraged to use tools that can supply incremental evolution, continuous integration, re-working, version management, and other Agile technologies.

Table 8.7 lists the key challenges with culture, skills, governance, and commercial aspects that government organizations have to overcome for Agile approaches to work.

Table 8.7: Key Challenges to overcome for Agile to work in Government
(Source: Myer and Yoxall, 2011)

Component	Challenges to Overcome
Culture	<ul style="list-style-type: none"> • Taking responsibility and not being afraid to make decisions quickly • Dealing with high level outcomes rather than clearly defined requirements • Wider engagement and integrated teams rather than ‘supplier-based’
Skills	<ul style="list-style-type: none"> • Making difficult tradeoffs and prioritizing effectively • Regular testing, planning and demonstration to handle risks
Governance	<ul style="list-style-type: none"> • Development needs to begin early without a highly detailed and fully specified business case • Suitable controls put in place for audit and risk management
Commercial	<ul style="list-style-type: none"> • 77 week procurement cycles versus 2 week Agile releases • Contracting for outcomes and assessing value for money and productivity

8.4.4.2 Transition Success Strategies

Carilli (2013) described ten success strategies for transitioning from traditional to Agile development approaches as follows:

1. Secure Management Commitment
2. Empower the Team
3. Understand the Collaborative Culture
4. Embrace Agile Methods
5. Develop a Roadmap and Initial Plans
6. Acquire an Agile Coach and Train the Team
7. Start Small and Gain Early Successes
8. Establish Agile Performance Measures
9. Create Agile Contracts
10. Adopt Application Lifecycle Management Tools to Facilitate Interactions

Agile methodology requires discipline. Organizations are strongly encouraged to consider applying these strategies along with strong business and IT management disciplines to position Agile projects for greater success. Table 8.8 lists the factors that may affect the success of the Agile project development process.

Table 8.8: Success Factors
(Source: Chow and Cao, 2008)

Dimension	Factor
Organizational	<ul style="list-style-type: none"> • Strong executive support • Committed sponsor or manager • Cooperative organizational culture instead of hierarchal culture • Oral culture placing high value on face-to-face communication • Organizations where Agile methodology is universally accepted • Collocation of the whole team • Facility with proper Agile-style work environment • Reward system appropriate for Agile
People	<ul style="list-style-type: none"> • Team members with high competence and expertise • Team members with great motivation • Managers knowledgeable in Agile process • Managers who have light-touch or adaptive management style • Coherent, self-organizing teamwork • Good customer relationship
Process	<ul style="list-style-type: none"> • Following Agile-oriented requirement management process • Following Agile-oriented project management process • Following Agile-oriented configuration management process • Strong communication focus with daily face-to-face meetings • Honoring regular working schedule – no overtime • Strong customer commitment and presence • Customer having full authority
Technical	<ul style="list-style-type: none"> • Well-defined coding standards up front • Pursuing simple design • Rigorous refactoring activities • Right amount of documentation • Regular delivery of software • Delivering most important features first • Correct integration testing • Appropriate technical training to team
Project	<ul style="list-style-type: none"> • Project nature being non-life-critical • Project type being of variable scope with emergent requirement • Projects with dynamic, accelerated schedule • Projects with small team • Projects with no multiple independent teams

8.4.4.3 Recommended Action Framework for Government Agencies

In the paper “Agile in the Federal Government: Scrum and Beyond” published by CC Pace Systems, Inc. in 2014, the authors identified and discussed a four-step framework that government organizations could adopt for a smooth Agile transition. These steps consist of:

1. **Assessment:** This step focuses on self-awareness, and identifying the organization's baseline position on the Agile techniques already adopted or being considered for adoption. The maturity model could be used to assess the baseline position of people, process, and organizational components. Furthermore, structured surveys and interviews help gather the information to assess the state-of-the-practice in adopting the Agile approaches.
2. **Roadmap:** This step focuses on identifying the target state, and developing a roadmap to achieve the target state. The focus is on identifying the best practices and lessons learned from the private sector and recognizing the unique aspects of the government agencies. Although Scrum has been the most popular Agile approach, other approaches such as Kanban should be explored for feasibility.
3. **Training:** This step focuses on knowledge acquisition. Since Agile is a new concept, training to help establish a common set of knowledge and expectations of Agile framework is essential. The training should also focus on the changing roles, responsibilities, and expected outcomes across the organization.
4. **Process Improvement:** As organizations begin to adopt Agile principles, *process coaches* are needed to provide guidance, direction, and encouragement to teams.

The U. S. Government Accountability Office (2012) identified ten practices that were found to be effective by five federal agencies that used Agile practices for their software development projects. The ten practices include:

1. Start with Agile guidance and an Agile adoption strategy.
2. Enhance migration to Agile concepts using Agile terms and examples.
3. Continuously improve Agile adoption at both project and organization levels.
4. Seek to identify and address impediments at the organization and project levels.
5. Obtain stakeholder/customer feedback frequently and closely.
6. Empower small, cross-functional teams.
7. Include requirements related to security and progress monitoring in your queue of unfinished work (backlog).
8. Gain trust by demonstrating value at the end of each iteration.
9. Track progress using tools and metrics.
10. Track progress daily and visibly.

8.5 Chapter Summary

The FDOT TSM&O Strategic Plan calls for enhanced goals to expedite the project development and delivery process. One of the initiatives is to consider the adoption of Agile project development methodologies. Transportation projects involving TSM&O/ITS strategies cannot be developed using traditional approaches, especially since the technologies involved can significantly change over time between initial conception and project completion. Although agencies begin the process with the end result in mind, all of the project requirements may not be well defined at the beginning of the development process. In other words, some of the features

and requirements that need to be addressed to meet the needs of the end users may not be clear at the onset. Thus, traditional project development approaches are not suitable for developing TSM&O/ITS projects.

Agile methodology offers an alternative to the traditional approach, and is a faster paced approach that is more value-driven, change-oriented, and collaborative. Agile methodology adapts to changing requirements, encourages self-organizing teamwork and active participation of users, stakeholders, and customers, and ensures quick completion through a small time-boxed work flow. It is commonly adopted for software development, and could potentially be adopted for TSM&O/ITS projects. Scrum, the most popular approach of Agile methodologies, offers an iterative, incremental approach to optimize predictability and manage risk.

Several government organizations have adopted the Agile principles for select projects. For example, Washington State has been using Agile principles for IT projects, Texas has used Agile framework to create a tool for their vehicle inspection service, and Tennessee DOT has used the Agile approach to build applications. Agile methodology and the Scrum framework offer a potentially suitable alternative to traditional project development approaches for TSM&O/ITS projects.

9 – TSM&O/ITS PROJECT PROCUREMENT OPTIONS

The transportation sector constitutes a wide variety of projects including highway construction, traffic engineering and operations, Intelligent Transportation Systems (ITS), Transportation Systems Management and Operations (TSM&O), and many others. Traditional construction projects focus on improving safety and mobility by primarily constructing and maintaining the physical roadway network. In contrast, TSM&O and ITS projects focus on optimizing the performance of existing multimodal infrastructure through implementation of systems, services, and projects to preserve capacity and improve the security, safety, and reliability of the transportation system.

Unlike traditional highway construction projects, TSM&O and ITS projects are usually based on technology and software applications that change continuously, often rapidly, and sometimes unexpectedly. Moreover, TSM&O and ITS projects are performance-based, and as a result are increasingly software-based to collect and analyze the quantity of data that is required to operate the system. Many public agencies that manage TSM&O and ITS projects have adopted project development approaches and procurement strategies that are more suitable for traditional civil engineering projects and often experience issues related to procurement time and Request for Proposal (RFP) details (too little or too much detail). As a result, the final product may not be what the agency expected, or may be too expensive, or already obsolete. The practice of using traditional processes, not tailored to TSM&O and ITS, limits the project development of these projects. Therefore, agencies must explore new and alternative project development and procurement processes.

The procurement of ITS and TSM&O projects often presents challenges for state and local transportation agencies. Existing procurement approaches, such as low-bid, etc., are tailored to traditional transportation projects, with pre-defined requirements that use the *Waterfall* method in the development process. Procurement processes for software-related ITS and TSM&O projects can be more challenging when using traditional approaches, especially if the new *Agile* and *Scrum* frameworks are adopted. To obtain the best result, the procurement process for TSM&O/ITS projects “must be flexible to accommodate the uncertainties of complex system acquisitions, but, at the same time, structured enough to ensure that the responsibilities of the participants are fully defined and their interests protected”. Given the rapid changes in technology, and the specialized procurement methods necessary for ITS and TSM&O projects, it is imperative to consider procurement methods that expedite bid, proposal, and contracting processes (Lakeside Engineers, LLC, & Pat Noyes and Associates, 2016).

This chapter focuses on assisting the FDOT with identifying alternative approaches to procure, budget, and develop ITS and TSM&O projects. Procurement processes for ITS and TSM&O projects are discussed in Section 9.1. FDOT’s guidelines for developing software-related projects are discussed in Section 9.2. FDOT’s existing practices for procuring software development projects, as well as, potential procurement and budgeting options are covered in Section 9.3, and

suggested recommendations pertaining to the procurement of ITS and TSM&O projects are offered in Section 9.4.

9.1 Procurement Process

This section is divided into two broad sub-sections. Section 9.1.1 briefly discusses the National Cooperative Highway Research Program (NCHRP) Report 560, *Guide to Contracting ITS Projects*. It presents the processes that could be adopted to procure ITS and TSM&O projects. It also provides recommendations contained in the NCHRP Report 560 for selecting the procurement process based on project complexity and risks associated with the ITS projects. Section 9.1.2 discusses existing practices in procuring ITS projects by other state agencies/organizations that may be adopted by FDOT for procuring software-related ITS and TSM&O projects.

9.1.1 Guidance in Procuring ITS Projects

The NCHRP *Guide to Contracting ITS Projects* based the procurement of ITS projects on the following eight steps (Marshall & Tarnoff, 2006).

1. **Make Initial Decisions:** It aids users in making fundamental procurement decisions that will ultimately affect the overall procurement strategy.
2. **Determine Work Distribution:** It helps users determine whether the procurement should be performed as a single contract or multiple contracts.
3. **Define Project Category:** It helps categorize ITS projects with respect to complexity and risk. Understanding project complexity and risks is critical in determining an appropriate procurement package. Project complexity and risks can be divided into the following four categories (see Table 9.1 for more details):
 - Category 1: Straightforward in terms of complexity and low overall risk
 - Category 2: Moderately complex and moderate overall risk
 - Category 3: Complex with high overall risk
 - Category 4: Extremely complex with a very high overall risk
4. **Determine Agency Capability Level:** It provides the framework for assessing transportation agency resources and capabilities, as well as the environment in which the project will be procured. Table 9.2 discusses the agency capability levels as a function of different characteristics.
5. **Select Applicable Systems Engineering (SE) Process & Candidate Procurement Package:** It uses the results of the previous steps to select an applicable SE process and identifies candidate procurement packages. Table 9.3 presents the decision matrix.
6. **Apply Differentiators:** It helps to reduce the number of candidate procurement packages identified in Step 5.

7. **Assess Procurement Package and Make Final Selection:** It provides the criteria for making the final selection of the most appropriate procurement package.
8. **Define Contract Scope & Terms and Conditions:** It assists users with the selection of the necessary terms and conditions to be included in the contract.

Table 9.1: ITS Project Categories and Associated Characteristics
(Source: Marshall & Tarnoff, 2006)

Factors	Category 1 Straightforward Low Risk	Category 2 Moderately Complex Moderate Risk	Category 3 Complex High Risk	Category 4 Extremely Complex Very High Risk
Level of New Development	Little to no new software development/ exclusively based on COTS software and hardware or based on existing, proven software and hardware.	Primarily COTS software/ hardware or existing software/ hardware based with some new software development or new functionality added to existing software-evolutionary development.	New software development for new system, replacement system, or major system expansion including use of COTS software. Implementation of new COTS hardware.	Revolutionary development - entirely new software development including integration with COTS or existing legacy system software. Implementation of new COTS hardware or even prototype hardware.
Scope & Breadth of Technologies	Application of proven, well-known, and commercially available technology. Small scope in terms of technology implementation (e.g., only CCTV or DMS system). Typically implemented under a single stand-alone project, which may or may not be part of a larger multiple-phase implementation effort.	Primarily application of proven, well-known, and commercially available technology. May include non-traditional use of existing technologies. Moderate scope in terms of technology implementation (e.g., multiple technologies implemented, but typically no more than two or three). May be single stand-alone project, or may be part of multiple-phase implementation effort.	Application of new software / hardware along with some implementation of cutting-edge software, hardware, or communication technology. Wide scope in terms of technologies to be implemented. Projects are implemented in multiple phases (which may be Category 1 or 2 projects).	New software development combined with new hardware configurations/components, use of cutting-edge hardware and/or communications technology. Very broad scope of technologies to be implemented. Projects are implemented in multiple phases (phases may be Category 1 or 2 projects).
Interfaces to Other Systems	Single system or small expansion of existing system deployment. No interfaces to external systems or system interfaces are well known (duplication of existing interfaces).	System implementation includes one or two major subsystems. May involve significant expansion of existing system. System interfaces are well known and based primarily on duplicating existing interfaces.	System implementation includes three or more major subsystems. System interfaces are largely well known but includes one or more interfaces to new and/or existing systems/databases.	System implementation includes three or more major subsystems. System requires two or more interfaces to new and/or existing internal/external systems and plans for interfaces to "future" systems.

Table 9.1: ITS Project Categories and Associated Characteristics (continued)

(Source: Marshall & Tarnoff, 2006)

Factors	Category 1 Straightforward Low Risk	Category 2 Moderately Complex Moderate Risk	Category 3 Complex High Risk	Category 4 Extremely Complex Very High Risk
Technology Evolution	Need to account for technology evolution perceived as minor. Example would be to deploy hardware and software that is entirely compatible with an existing COTS-based system. Ramifications of not paying particular attention to standards considered minor. System implemented expected to have moderate to long useful life.	Need to account for technology evolution perceived as an issue to address. Example includes desire for interoperable hardware from multiple vendors. Ramifications of not paying particular attention to standards may be an issue, as an agency may get locked into a proprietary solution. Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have moderate to long life.	Need to account for technology evolution perceived as a significant issue. Examples might include implementation of software that can accommodate new hardware with minimal to no modification and interoperable hardware. Ramifications of not using standards based technology are considerable (costs for upgrades, new functions, etc.) Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have an extendable useful life.	Need to account for technology evolution perceived as major issue. Examples include software that can easily accommodate new functionality and/or changes in hardware and hardware that can be easily expanded (e.g., add peripherals), maintained, and are interoperable. Ramifications of not using standards-based technology are considerable (costs for upgrades, new functions, etc.). Field devices expected to have moderate to long useful life. Center hardware life expectancy is short to moderate. Control software is expected to have an extendable useful life.
Requirements Fluidity	System requirements are very well defined, understood, and unlikely to change over time. Formal requirements management a good idea, but not a necessity.	System requirements are largely well defined and understood. Addition of new system functionality may require more attention to requirements management.	New system functionality includes a mix of well-defined, somewhat-defined, and fuzzy requirements. System implementation requires adherence to formal requirements management processes.	System requirements not well defined, understood, and very likely to change over time. Requires strict adherence to formal requirements management processes.
Institutional Issues	Minimal - Project implementation involves one agency and is typically internal to a particular department within the agency.	Minor - May involve coordination between two agencies. Formal agreements not necessarily required, but if so, agreements are already in place.	Significant - Involves coordination among multiple agencies and/or multiple departments within an agency or amongst agencies. Formal agreements for implementing project may be required.	Major - Involves coordination among multiple agencies, departments, and disciplines. Requires new formal agreements. May require new multi-agency project oversight organization.

Table 9.2: Agency Capability Levels as a Function of Characteristics
(Source: Marshall & Tarnoff, 2006)

Characteristic	Level 1	Level 2	Level 3
Personnel Experience	ITS assigned as part-time job to person with no staff and little to no specific ITS experience.	ITS assigned as full-time job with no staff or some part-time staff support. Person assigned has some specific ITS experience with Category 2 or 3 projects. Staff support (if it exists) has little to no ITS experience.	Full-time ITS manager and staff with significant prior ITS experience. Staff support includes system administration, operations, and maintenance responsibilities.
Organizational Experience	Little to no experience with the possible exception of Category 1 ITS project(s).	Experience with at least one Category 2 or greater project.	Experience with at least one Category 3 or greater project.
Organizational Structure	ITS responsibility not defined. Responsibility housed within organization with other mission or primary responsibility. Responsibility may also be scattered among organizational entities with no clear lines of responsibility.	ITS responsibility somewhat, but not adequately defined. Individual organizational units have ITS responsibility and have their own budgets, management, and priorities; however, there is no definitive linkage among these units. An umbrella ITS organizational unit may exist, but may not have the budgetary authority to effectively manage subunits.	Established organizational unit with budgetary authority and clear ITS responsibilities. Organizational unit ties all ITS responsibilities together and includes a procurement process that supports ITS acquisition (e.g., personnel, policies, and procedures).
Resources	Little to none. No identifiable ITS budget categories or identification of specific ITS funding within existing organizational units.	Some budget resources (e.g., ITS earmark funding) assigned to one or more existing organizational unit(s). Support for personnel, equipment, office space, and training expected to come from existing budget of organizational unit(s).	Identifiable budget category set aside for ITS. Budget includes support for all required personnel, support equipment, office space, training, and (if necessary) consulting support.
Management Support	Some mid-level management support for ITS/Operations, but little to no interest at top management levels. ITS/Operations not recognized as an agency priority.	Strong mid-level management support for ITS/Operations, with some interest/involvement at top management levels.	Top-level management support. ITS/Operations considered an agency priority within its overall mission.
Expectations	Not defined or limited to a lower category ITS project under consideration for deployment, expansion, or replacement.	Expectations exist for a few “special” ITS-related projects. Expectations may or may not be realistic depending on whether they have been managed properly.	ITS/Operations is part of both short- and long-range planning. Expectations are well defined with actual performance measures. ITS/Operations expectations focus on improvement and not on status quo.

Table 9.3: The Decision Matrix

(Source: Marshall & Tarnoff, 2006)

Project Category	Agency Capability Level		
	Level 1	Level 2	Level 3
1: Straightforward	<ul style="list-style-type: none"> • Waterfall • SM* 	<ul style="list-style-type: none"> • Waterfall • Low bid*, commodity, or systems manager 	<ul style="list-style-type: none"> • Waterfall • Low bid, commodity, or systems manager
2: Moderately Complex	<ul style="list-style-type: none"> • Evolutionary • Systems manager or design-build* 	<ul style="list-style-type: none"> • Waterfall or evolutionary • Low bid*, systems manager, or design-build 	<ul style="list-style-type: none"> • Waterfall or evolutionary • Low bid, systems manager, or design-build
3: Complex	Not recommended	<ul style="list-style-type: none"> • Evolutionary • Systems manager or design-build 	<ul style="list-style-type: none"> • Evolutionary or spiral • Systems manager or design-build
4: Extremely Complex	Not recommended	<ul style="list-style-type: none"> • Evolutionary or spiral • Systems manager or design-build 	<ul style="list-style-type: none"> • Evolutionary or spiral • Systems manager or design-build

Notes: First line is the systems engineering model; second line is the procurement package.

* Consulting services should be used while project is under way.

9.1.2 Existing Practices in Procuring ITS Projects

This section discusses the following agencies' existing practices in procuring ITS projects:

- Cape Cod National Seashore
- Iowa DOT
- Virginia DOT
- Missouri DOT

9.1.2.1 Cape Cod National Seashore

(Source: John A. Volpe National Transportation Systems Center, 2011)

Although Cape Cod National Seashore, a national park in Cape Cod, Massachusetts, is not a transportation agency, the organization is highly interested in acquiring ITS technologies and services to improve parking management at its beach parking areas. In recent years, the organization has been considering implementing ITS technologies to record vehicle counts, detect vehicle types, convey real-time parking availability information to visitors, and deploy electronic payment system.

The organization made the following recommendations for procuring the ITS technologies and services. Note that the below recommendations were adapted to be applicable to the broader audience.

- **Use Design-Build Approach:** A Design-Build contract, procured through a competitive RFP process, will provide a “turnkey” project. The winning contractor will be responsible for overall project execution, including installation and testing. The contractor’s bid package will specify subcontractors to perform engineering tasks such as mapping systems specifications to functional requirements, systems integration, computer programming, etc. Procuring all necessary services with a single contract will be much simpler than having to procure them separately. An additional benefit of using a design-build approach is that a single, large contract may attract more bidders, and better qualified bidders, than would a series of small contracts.
- **Use Best Value Procurement:** Although many goods and services are appropriately procured through lowest cost bidding; the low-bid procurement approach is not often suitable for ITS investments. The price of the ITS deployments must be balanced against qualifications and expertise.
- **Get a Warranty:** It is recommended for the winning bidder to warranty all components, engineering, and workmanship against defects. The length of the warranties offered by the competing firms should be among the criteria used to select a winner.

9.1.2.2 Iowa DOT

(Source: Lakeside Engineers, LLC, & Pat Noyes and Associates, 2016)

Iowa DOT’s Office of Traffic Operations (OTO) and Purchasing Section have worked closely together to manage and support TSM&O activities. In particular, OTO plays the leading role in developing technical requirements, and the Purchasing Section provides administrative support. Close coordination between the OTO and the Purchasing Section is deemed essential to be adequately prepared for bids, proposals, and contracting processes for ITS and TSM&O projects.

The following recommendations were made to Iowa DOT for procurement of TSM&O projects:

- Continue to investigate funding sources and mechanisms to provide for program planning and sustainable TSM&O funding.
- Transition TSM&O budgeting activities to a five-year cycle, consistent with the 5-Year Program.
- Clarify technical specification roles of OTO, Purchasing, and Office of Design staff.
- Diversify procurement process expertise in OTO by designating staff authorized to carry out development of RFPs on behalf of OTO.
- Establish streamlined processes for consultant contracting and associated accounts payable activities.

9.1.2.3 Virginia DOT

(Source: Ashuri & Kashani, 2012)

Virginia DOT has been using the design-build approach for a variety of projects including ITS projects that involve software development and rapidly changing technologies. Some of the advantages in using Design-Build, as identified by Virginia DOT, are:

- provides increased flexibility to modify the design approach and equipment used based on changes in technology;
- allows Virginia DOT to place increased emphasis on contractor qualifications and their technical approach in conjunction with cost considerations;
- provides a mechanism to “jumpstart” ITS design activities in Districts that have limited technical staff able to perform much of the initial design work; and
- permits greater input on project design from ITS vendors and systems developers.

9.1.2.4 Missouri DOT

(Source: Sauter et al., 2007)

Missouri DOT has frequently used low-bid methods of award for procuring ITS equipment. Unfortunately, this approach does not always provide the system with the best value for the dollars invested. ITS equipment is specified according to the desired functionality requirements of intended use. Since the deployed ITS equipment has to work as an integrated system, agencies cannot consider the ITS equipment in isolation, but as a part of an integrated system. In addition to the capital investment, agencies have to consider the continued costs of maintenance and operations. As such, equipment performance, as it relates to operational costs, may need to be considered to expend more funds upfront.

Understanding the challenges associated with procuring ITS equipment, Missouri DOT believes that Districts need to share their experiences and, where possible, procure similar technology. There is a need for DOTs to maintain a state repository of information about what was procured and why for all projects. Also, a systematic process to inventory the ITS assets is recommended.

Missouri DOT recommends including contingency plans within the procurement processes. All ITS procurements could include a section discussing the need for contingency plans and how they will be established. Furthermore, clear lines of responsibility need to be identified and delineated regarding ITS between the State Central Office, Districts, MPOs, and Regional Planning Commissions (RPCs). This approach will also ease issues with day-to-day interaction between the organizations throughout the ITS lifecycle.

In addition to the aforementioned recommendations, Sauter et al. (2007) also included the following best practices. Note that these ideas were adapted from Bannister (2004).

- Ensure that requirements are specified fully. When requirements are volatile, the package needs to be flexible.
- Follow evaluation methods to ensure advertised functionality is truly included.
- Build an acceptance test into the contract. This gives DOT the right to ensure that the package meets requirements and will perform adequately.
- Talk to others (regions, states, national contacts) where possible about the software and their experience with it.
- Build performance guarantees into the contract.
- Build support, training, and software evolution into the contract.
- Review software companies certification documents where they state they follow specific standards. Often companies have waivers or omissions in the documents and these are missed in the procurement process.
- Freeze requirements prior to procurement or development.
- Build a clear change/enhancement request procedure with costs associated into the procurement.

9.2 FDOT’s Guidelines to Developing Software-Related Projects

Since a majority of ITS and TSM&O projects are software-intensive, this section attempts to identify the Office of Information Technology (OIT) guidelines that could be adopted when developing software-related ITS and TSM&O projects.

Figure 9.1 shows FDOT’s current Information Technology (IT) Strategic Plan. Three initiatives (Governance, Information Management, and Standards) are identified as key items for IT Strategy to accomplish FDOT’s ITS Program mission to “enhance the safety, efficiency, and reliability of Florida’s transportation system through the use of best management practices and proven operational strategies” (FDOT, 2014b).

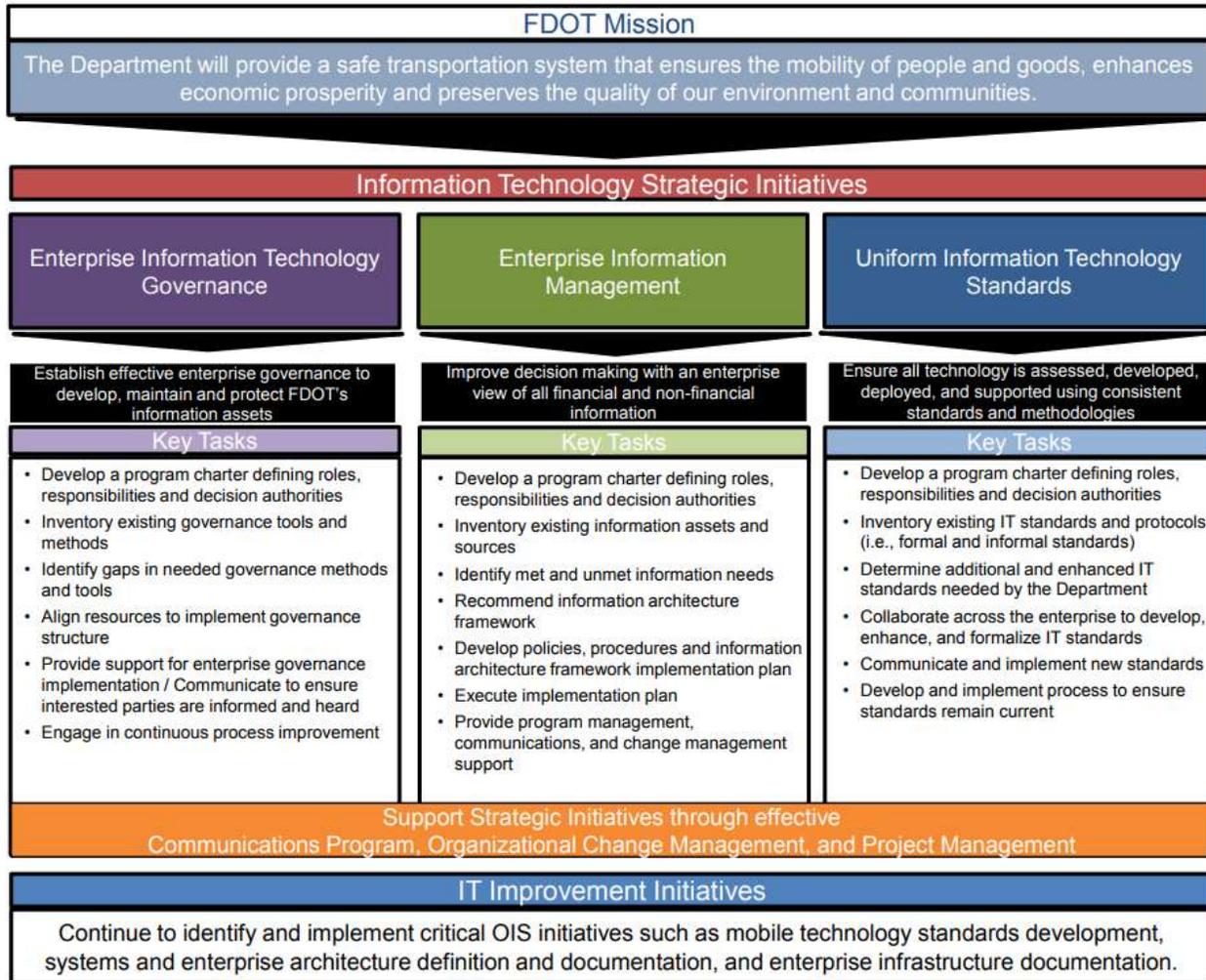


Figure 9.1: FDOT IT Strategic Plan
(Source: McCullion, 2014)

9.2.1 IT Standards

IT standards ensure effective and efficient management of IT investments through specifying acceptable technology products, and thus preventing spending on duplicative or obsolete technology. FDOT obtains IT services through a hybrid model of centralized and decentralized delivery and support. The OIT is the primary FDOT unit tasked with delivery of IT services. At present, FDOT districts, the Florida Turnpike Enterprise (FTE), ITS divisions, and non-OIT Central Office groups obtain IT services outside the oversight of OIT. IT standards are particularly important in such environments where applications developed by one organizational unit may benefit another. Without an agency-wide IT standard, it is difficult for FDOT as a whole to take advantage of successful development efforts that occur in Districts and other FDOT groups.

The overall assessment of the OIT Methods and Practices documents is that the infrastructure applicability is mainly for OIT managed systems and does not cleanly or linearly extend to ITS programs and the IT infrastructure at the Regional Traffic Management Center (RTMC). FDOT districts and non-OIT Central Office groups are obtaining outsourced application development services beyond the purview and oversight of OIT.

By the OIT encouraging standardization of the ITS/IT infrastructure among the seven District offices, the FTE which maintains two Transportation Management Centers (TMCs), and the Central Office which also maintains a TMC in Tallahassee, the utilization of industry Best Practices could be ensured. To effectively standardize ITS/IT infrastructure requirements, an in-depth understanding is needed of the unique operational needs and systems requirements of TMCs, many operating 24/7. The existing Methods and Practices documents would need to be updated and extended, specifically noting applicability to the IT infrastructure at District TMCs.

9.2.2 Application Development Documentation and Guidelines

The FDOT OIT (2017j) provides Application Development Standards for the following set of applications:

- Web Application Standards
- Static Website Standards
- Web Application color Palette
- .NET Code Review Standards
- Multimedia Standards
- FDOT Development Environment
- SQL Review Standard
- Database Design Standards
- Logical / Physical Object Naming Standards
- Requirements Deliverable Standards
- Application Testing Standards.

9.2.3 IT Governance

IT governance “provides a structure for aligning IT strategy with the organization’s business strategy” (Lindros, 2017). It is essential to ensure that IT related activities follow the organization’s IT standards, policies, processes, and procedures. An established IT guidance allows FDOT to review and approve IT infrastructure design, procurement, and implementation.

The current governance procedures for IT-related ITS services (e.g., major purchase or any important technology direction) consist of the following three steps:

1. Major purchases and projects are discussed over multiple review sessions between FDOT management and relevant IT and ITS staff to validate alignment with short-term and long-term goals and confirm FDOT’s expected outcomes for the project tasks.

2. Multiple options for design and implementation are presented and discussed with FDOT to ensure there is proper due diligence concerning final outcomes.
3. Numerous factors such as long-term costs, life cycle dates, track record of the vendor in the industry, technical needs, strength of vendor support, price, etc. are assessed, and are all taken into consideration prior to recommending a solution for purchase. The results of these evaluations are presented to FDOT as part of the value proposition of one potential option versus another.

9.3 Project Types

This section first categorizes TSM&O/ITS projects into software-related and non-software projects. It next discusses FDOT's existing practice in procuring and budgeting software-related projects. The different budgeting and procurement options that are available for both software-related and non-software TSM&O/ITS projects are then presented. As part of this research effort, the research team interviewed Mr. James Barbosa, Director of the IBI Group (Florida) Inc. The information provided in this section is obtained from the interview (J. Barbosa, personal communication, October 10, 2017).

A majority of TSM&O/ITS projects are not entirely software-related, but often include hardware modifications and field devices. Nonetheless, almost all these projects have at least minor software development/enhancement components. As such, TSM&O/ITS projects can be divided into two broad categories – software-related projects and non-software projects, and are discussed in the following sections.

9.3.1 Software-related Projects

This section focuses on TSM&O/ITS projects that are software-intensive. Software-related projects may constitute:

- only the software component,
- both software and hardware components,
- primarily software and hardware components with some field devices, or
- primarily field devices with some hardware and some software modifications.

9.3.1.1 FDOT's Existing Practice

In general, FDOT staff and General Engineering Consultants (GECs) are not always well positioned to specify software requirements. One approach is to develop detailed specifications for a solution. However, this would require a significant amount of time and resources on the part of FDOT, and in the end, these specifications may not satisfy all the requirements. Oftentimes, FDOT staff involved in creating a specification seldom have a software background, particularly in the area of software application. This scenario is not unique to FDOT; almost all government agencies are faced with similar issues.

The FDOT's current approach uses the Waterfall project development process to develop software systems, which often results in two projects. When the initial specifications are provided, a software company wins the contract, builds the product to specification, and then delivers the product. After FDOT staff start using the product, additional functionalities that are currently missing or need enhancement are identified. Invariably, a second project (or Phase II) is required to fix the issues identified in the original project. The Phase II of a project is usually considered as *Enhancements*, and typically occurs with most ITS deployments.

When a contract is advertised with requirements, some FDOT project managers firmly commit to the Waterfall model, and require the development team to develop the product to all the pre-defined requirements. On the other hand, some project managers may treat the pre-defined requirements as a guide to allow the design to evolve over time based on review and feedback. For example, the enhancements to the *FL511.com* website were done using an iterative approach, with the majority of the changes not identified in the initial RFP. The development team understood that an iterative process was needed. Likewise, the FDOT project manager understood the importance of developing and improving the product, rather than just creating and updating the pertinent documentation.

A similar approach, using Agile principles, was adopted for making enhancements to the Maintenance and Inventory Management System (MIMS) application. For this project, the development team had a very brief Task Work Order containing only high-level requirements. Therefore, the team adopted an iterative process requesting constant input from FDOT staff, and incorporated all the enhancements in three iterations.

A more effective and efficient approach would involve FDOT defining the core high-level requirements of the system upfront to help establish the potential framework of the solution. The development team could use the Agile project development process specifically with this framework and within the pre-defined constraints. Typically, the high-level requirements may focus on the user interface and user interaction, as user interface is the window into the rest of the system. The question is how much detail should be provided in the functional requirements phase, and how much should be addressed in the detailed design phase of the project. Enough information has to be provided to be able to reasonably cost the effort and create a reasonably accurate schedule without constraining the design to the degree that the development team has to redo, redesign, or rebuild the solution shortly thereafter.

9.3.1.2 Budget

Budgeting for software development projects is typically difficult, especially if the software development project adopts the Agile project development process. FDOT currently requires that the budget be established and encumbered upfront. However, this requires a fairly accurate initial estimation of costs by FDOT staff members.

If the *Agile* project development process and Scrum framework are adopted, having the higher-level functional requirements (or use cases and feature descriptions) does allow a software company with experience in the area to essentially predict how many design iterations are required to develop the system. In other words, if high-level requirements are available, an experienced software development firm can budget for it.

The more uncertainty that exists about the clients and the solution, the greater the need to budget for the effort. The amount budgeted depends on the risk management from the perspective of the development team. As long as the framework is well-defined, and the work is given to a reputable software company that has experience with Agile procedures, budgeting is usually not an issue.

FDOT can help mitigate the risk by stipulating or stating the desired expectations upfront. For example, FDOT could state in the RFP that a minimum of three iterations are required to design a specific component. This approach will assist FDOT in estimating the budget. It will also ensure that FDOT would not inadvertently select a software company that is unfamiliar or inexperienced with the Agile environment.

While a possible approach to budget for these projects is to purchase *service hours* from the development team, it is not recommended. The issue with this approach is that the risk falls entirely on the FDOT, and there is no incentive for the development team to be efficient. A lack of efficiency incentives may result in higher costs for the FDOT.

9.3.1.3 Alternative Procurement Options

FDOT typically provides detailed initial specifications for developing a software system. One of the fundamental challenges with this approach is that it is difficult for the development team to follow highly detailed requirements specifications, and translate that information into a detailed design. The Agile approach allows the end user to very quickly see the product, and provides a much easier environment to identify shortcomings in the specifications. The Agile framework also allows for flexibility in the first design iteration. In other words, the requirements are scaled back to the functional and high-level requirements to focus on the use cases as opposed to being detailed and spending too much time on *how* it should be done. This allows the development team to utilize their experience in developing software that provides a better user experience and a better solution, and provides alternative means for implementing solutions to comply with the specifications. Within the Agile approach, each iteration where some of the functionalities are accepted by the project manager could be considered as a deliverable.

There are two feasible options to procure software development projects. The first approach requires FDOT to have framework requirements and/or framework use cases established, such as a Concept of Operations (ConOps) document. The document does not need to be all-inclusive; however, it does need to focus on *what* the system must do and not *how* it does it. In other words, the RFP needs to focus on the functionality and not the design. Included in the RFP, advertised by FDOT, must be the expectation that there will be significant iterative participation in the

design process, especially pertaining to user interaction and user interface. These are areas generally not covered by the functional requirements. Additionally, these actions help promote Agile development within the existing framework, thus lessening the overall costs. This approach ensures that FDOT receives the solution that meets their needs in a timely manner with less costs.

A second, more practical approach in procuring software development projects is to have a *Proof of Concepts* first, followed by the entire development phase. It is not necessary for same company to do both phases. In other words, Phase I (Proof of Concepts Phase) focuses on generating, revising, and finalizing all the system user interfaces and workflows, which generally capture all functionalities of the system. In this phase, a software company, for example, essentially works with FDOT on a limited budget to generate, review, and refine the workflows and all system user interfaces. This phase of the project does not require code development. Simple applications such as Photoshop or other currently available wire-framing tools could be used to very quickly construct a mock-up, or proof, of the user interface for review. This approach can be easily budgeted by FDOT as there is very little actual software development involved. This phase essentially uses the Agile process. The next phase, Phase II, focuses on developing the actual product. FDOT may elect to develop a second RFP for Phase II, if desired. For Phase II of the project, the companies will bid on the ConOps to implement the designs finalized in Phase I. Since all of the information is already available from Phase I, the Agile approach, if adopted for Phase II, will only be used for minor refinements. The Waterfall model can also be adopted for Phase II.

For example, Phase I (Proof of Concepts Phase) could be completed in-house. FDOT staff and their GEC partners in the Districts who are working in the TMCs could use the Agile process to develop, review, and refine the workflows and system user interface needs. This can be accomplished through Task Work Orders to the GEC team to fit the needs of the FDOT, and can also be expedited contractually. Once Phase I is completed, FDOT may elect to develop an RFP for Phase II.

In summary, either of the two approaches are viable options for procuring software projects, and depend on the time and effort FDOT wishes to invest. However, the second approach consisting of two phases to develop the project may be more suitable and practical for procuring software-related TSM&O/ITS projects.

9.3.2 *Projects with Minor Software-related Components*

Almost all TSM&O/ITS projects have at least minor software development/enhancement components. Traditional project development and procurement processes may not be suitable for projects with software-related components. In such cases, the Waterfall approach could be adopted for non-software components, with Agile principles adopted for software-related components. Traditional procurement procedures are suitable for non-software components, while the two-phase approach discussed in Section 9.3.1.3 would be suitable for software-related components.

9.3.3 Non-software Projects

The non-software TSM&O/ITS projects may constitute:

- primarily hardware components with some field devices, or
- primarily field devices with some hardware modifications.

The non-software projects do not require adoption of new and alternative procurement and budgeting approaches. For these types of projects, FDOT could continue to use the traditional Waterfall project development process, and the traditional procurement practices. However, if the FDOT foresees a need for additional flexibility in procuring hardware components, a two-phase approach, as discussed in Section 9.3.1.3, could be considered. Phase I could focus on identifying the equipment that is compatible; and Phase II could focus on purchasing and setting up the equipment.

10 – CASE STUDIES

This chapter examines projects mentioned by project managers in the survey that may serve as case studies for the successful implementation of TSM&O strategies. For the purpose of this report, “successful implementation” refers to projects where a TSM&O strategy was identified as the preferred alternative or solution to address a capacity or safety issue. Projects describing missed opportunities where TSM&O strategies could have provided a viable solution are also briefly discussed.

TSM&O/ITS and Traffic Operations project managers that mentioned successful TSM&O deployments in the survey were interviewed to share details about the project listed, as well as their experiences. Questions asked of each project manager included:

- How did the project come about?
- Who made the final decision?
- Who was involved in the decision-making process?
- Is there documentation of the decision-making process available?
- Was the Systems Engineering Process (SEP) used?
- What parts of the project went smoothly?
- What parts of the project were difficult?
- Were future TSM&O components selected early in the project although funding was not available?
- Were there any roadblocks experienced with other project managers?
- Were there any guideline issues?

Project managers in Districts Two (D2), Three (D3), Five (D5), Six (D6), and the FTE responded in the survey as having successful TSM&O implementation on a project in their district. The majority of these project managers also mentioned missed opportunities for TSM&O consideration. Although survey participants in Districts One (D1), Four (D4), and Seven (D7) did not mention either successful or unsuccessful TSM&O deployments in the survey, project managers in each of these districts were also contacted to discuss the state-of-the-practice of TSM&O in their District.

10.1 Successful TSM&O Implementation

Projects listed by TSM&O/ITS and Traffic Operations project managers, where TSM&O strategies were identified early in the project development process as the preferred solution, are discussed in the following subsections. Both successful elements and challenges experienced during the course of each project are presented. Several projects mentioned are currently underway in various stages. However, challenges and lessons learned as these projects progress offer valuable information that may be beneficial for future TSM&O deployments.

10.1.1 Integrated Corridor Management (District 2)

In District 2, integrated corridor management was used along Philips Highway (US 1), a 10.5 mile section parallel to Interstate 95 (I-95) and south of downtown Jacksonville, as shown in Figure 10.1. The project, generated by the North Florida Transportation Planning Organization (TPO), and managed by the District, serves as a means to mitigate congestion along the adjacent I-95 section resulting from an incident, and detour traffic around and back onto the Interstate. Funded by the Surface Transportation Program (STP) authorized by the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), the project was completed within three years, from conception to acceptance.

During the course of the project, a number of challenges and lessons learned were experienced. Nevertheless, the integrated corridor management system on Philips Highway has been successful in mitigating congestion due to crashes along the adjacent section of I-95.



Figure 10.1: Philips Highway Integrated Corridor Management Project Location Map

Source: North Florida TPO, www.floridatpo.com

10.1.1.1 Project Challenges

A major challenge with this project was that both facilities, Philips Highway and I-95, were already operating at full capacity during peak hours. To manage the additional traffic placed on Philips Highway during an incident occurrence on I-95, a revised timing plan was developed that could be activated as needed. TSM&O components included upgraded traffic signal controllers, signage, and Closed Circuit Television (CCTV) cameras with Bluetooth technology incorporated. All system requirements needed for the project met the allotted budget.

After the project estimate was completed, the next step was to determine the project delivery and procurement method. FDOT decided on the Design-Build (DB) Low-bid method of delivery and procurement rather than the System Manager approach, often preferred by D2 TSM&O staff. The perception at the time was that the DB method, often used with other types of transportation projects, would provide a faster delivery at a lower price. As with many Design-Build projects, the Systems Engineering (SE) process was not used for this project. The final price of the project actually came in higher than expected and was completed much later than scheduled.

Although devices and components are tested for quality and performance prior to being approved for use by the Traffic Engineering Research Lab (TERL) in Tallahassee, the Florida environment often affects the long-term performance of products. With the Design-Build project delivery method, the selection of devices specified by the District was at the sole discretion of the contractor. The contractor chose the least costly components on the Approved Product List (APL), regardless of concerns expressed by the D2 project managers relating to long-term performance quality or network integration compatibility. This practice ultimately resulted in extensive replacement efforts by the District after the project was accepted, and at additional cost to the District.

All of the devices used on the Phillips Highway project passed the testing phase and worked at the time the project was accepted by the FDOT. However, failures occurred shortly thereafter. One example is the cable selected by the contractor, which eventually failed due to lack of shielding, and resulted in the District having to replace all of the cable on the project. Network devices selected by the contractor, also did not fit within the current DOT network, requiring the District to replace a number of switches. In some instances design elements were affected, such as preferred device locations moved by the contractor to minimize expense.

Lack of knowledge and expertise by the Construction Engineering & Inspection (CEI) subcontractor was also a factor on the project. The sub-consultant replaced their project manager four different times due to lack of knowledge and experience.

10.1.1.2 Lessons Learned

The Design-Build project delivery method is a price-driven method that may allow little to no control by DOT regarding ITS system components. It is not clear whether contract specifications played a role in the issues experienced on this project. However, careful attention should always be taken when developing contract specifications so that the needs and expectations of the TSM&O project manager are met in order to achieve the project goals.

The System Manager approach gives DOT full oversight over the design and selection of system devices. With System Manager, DOT purchases the products that work best for the project's purpose and need, and assumes the responsibility for the performance of those products. Cost savings can also be realized through vendor discounts to State agencies, and fewer repair and/or replacement costs.

Although contractors doing business with FDOT are required to select products on the APL, some products perform better than others in the hot Florida environment. Much of this information is based on project manager experience from previous projects. Finding a way to incorporate this knowledge into the project development process needs further exploration.

10.1.2 Congestion Management (District 3)

Currently in the design phase, District 3 is implementing a robust incident management and active management plan on the Pensacola Bay Bridge Replacement project both during construction and after completion. The existing bridge is a heavily traveled three mile facility connecting the cities of Pensacola in Escambia County and Gulf Breeze in Santa Rosa County, as shown in Figure 10.2.

Congestion on the bridge has been an issue for a many years. A number of studies have been performed in previous years, with the Project Development & Environment (PD&E) process completed for nearly a decade, and recently updated. This Design-Build project, scheduled to take three to five years to complete at a cost of nearly \$500 million, was moved up in the Work Program due to the structural deficiency of the existing bridge. A benefit-cost analysis determined that maintenance costs for the existing structure were projected to increase considerably; therefore, replacement and congestion management was the best option. Upon completion, the new structure will be outfitted with cameras, Bluetooth sensors, and an infrared camera at the south top of the bridge due to fog potential, and will be actively monitored by the SunGuide Center in Pensacola.

10.1.2.1 Project Challenges

The existing bridge lane configuration of two narrow lanes in each direction with narrow shoulders prompted the need for a strong incident management plan during construction of the new bridge. Collaboration with the District's General Engineering Consultant (GEC) determined that Road Rangers and a wrecker service should be available 24 hours a day, seven days a week. The contractor must submit an incident management plan to the District, as well as conduct traffic incident management team meetings involving all stakeholders, including law enforcement and other first responders.

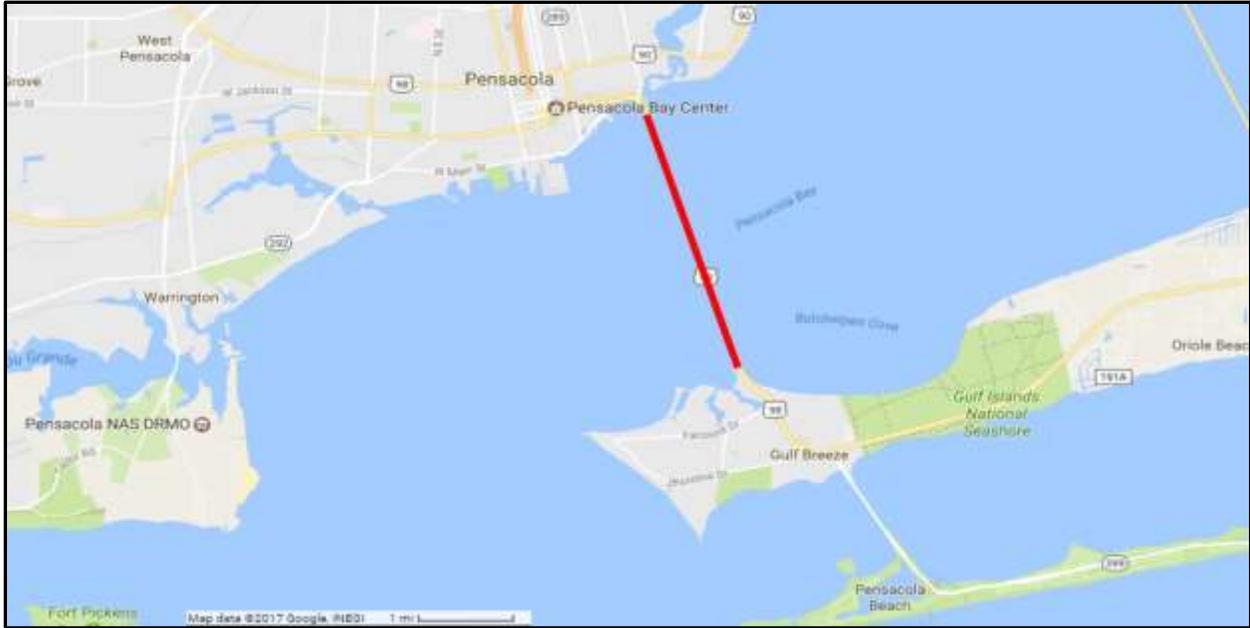


Figure 10.2: Pensacola Bay Bridge Replacement Project Location Map

Source: Google Maps, 2017

An active traffic management plan is also required, with sensors and cameras installed on the existing bridge, and monitored in real-time at a nearby temporary traffic management center prior to the start of construction. Real-time information will be shared with the public and the FDOT. Maintaining a uniform speed during construction to prevent back-of-the-queue crash occurrence is also required. To ensure that the contractor meet these requirements, District TSM&O staff worked closely with the GEC to develop strong language in the Request for Proposal (RFP).

There is also a need for traveler information at each approach to the bridge, especially because the bridge has a significant vertical rise preventing drivers from seeing the other side. Although Dynamic Message Signs (DMSs) were included in the original contract, they were subsequently removed for aesthetic reasons.

10.1.2.2 Lessons Learned

Public perception of the project has become controversial due to uncertainty of what to expect during construction. Early on, incident management has been a concern. The considerable price tag to replace the existing bridge has some residents questioning the Design-Build process and how active traffic management will work to their benefit. However, an ongoing public relations effort by the FDOT to inform the public has been helpful in addressing these concerns. The District hopes that incident management and active traffic management during the construction phase will provide more support for the project. Informing the public is a key component for the successful deployment of TSM&O strategies on large-scale and high profile projects.

10.1.3 Safety Improvements (FTE)

The FTE implemented TSM&O strategies in the way of safety modifications through signing and pavement marking revisions to reduce run-off-the-road type crashes at interchange exit ramps along the turnpike. Crash data is routinely analyzed by the Operations and Maintenance group to identify high crash locations on the facility. Although, no formal study was conducted, in-house analyses found that interchanges with sharp curves and loop ramps experienced a greater number of incidents. One alternative considered was to completely revise the geometry of each interchange to provide a more direct movement; however, this alternative was deemed too costly and would be a long-term approach. To improve safety conditions in the short term, Operations staff made the decision to add chevron signs, advance speed advisory signs, and curve warning signs at a number of interchanges, as shown in Figure 10.3. The majority of the safety modifications were designed in-house through collaboration with the GEC, and funded primarily with Maintenance funds. This process has continued for nearly six years.

Although these projects were ad hoc, and generated exclusively by the O&M office, this example highlights a TSM&O strategy that does not contain ITS components. In some cases, project managers were able to insert additional signing and pavement markings as early as the design phase of a construction project. Results reveal a marked reduction in the number of crashes at locations where these safety modifications have been installed.



Figure 10.3: Safety Improvements Example on Turnpike Exit Ramp

Source: Google Maps 2017

10.1.3.1 Project Challenges

The biggest challenge for project managers was coordinating improvement plans, location by location, to identify which interchanges were not scheduled for upgrades or replacement in the near future. If a construction project was scheduled within the next two to three years, Operations project managers worked with designers to either insert the signing and pavement markings or revise the design to improve safety.

10.1.3.2 Lessons Learned

Since the safety modifications were funded by Maintenance, Operations engineers had full oversight during each project. This resulted in a fairly smooth process with little to no difficulties experienced.

10.1.4 I-95 Express Lanes (District 6)

One of the earliest examples of TSM&O implementation occurred in District 6 with the conversion of existing High Occupancy Vehicle (HOV) lanes to High Occupancy Toll (HOT) lanes, also known as express lanes. Funded with both Federal and State funds, FDOT made the decision to convert the lanes as early as 2006 during the planning phase of the project development process. At the time, the concept of express lanes and dynamic pricing was new to the District and to the State. The express lanes are adjacent to the general-use driving lanes along I-95 in both directions, and separated by a flexible plastic pole barrier (express lane markers). However, drivers must enter and exit the express lanes at designated points along the facility, as shown in Figure 10.4. Dynamic congestion-based tolls are collected electronically with SunPass transponders and vary based on the current level of congestion. Figure 10.4 shows an example of the toll pricing feature.



Figure 10.4: I-95 Express Lane Entrance and Dynamic Pricing Example

Source: www.95express.com / www.wlrn.org

Key to the project's success, was the involvement of Operations at the very beginning and throughout the project development process – planning, PD&E, design, and construction. The SE process was followed, and the Central office was heavily involved due to the high profile nature of the project. Because this project marked a new initiative for FDOT, the entire process was basically a learn-as-you-go effort with very little experience or guidelines to provide assistance.

Northbound I-95 express lanes opened in 2008, and southbound express lanes opened in 2010 following the reconstruction of a major interchange along the route. Although considerable challenges were experienced throughout the project development process, the end result was a success. Challenges experienced on this project were also instrumental in the development of the *Express Lane Handbook* years later.

10.1.4.1 Project Challenges

Aside from the given challenge of undertaking a new transportation concept, a major challenge for this project was educating the public about HOT lanes in general – what to expect, and how to use them. A comprehensive media campaign was launched using billboard displays, newspaper advertisements, and radio spots. Highway advisory radios already in place were utilized, with signage asking the public to dial into the radio station for information. Nevertheless, when the northbound express lanes were opened, many drivers would enter the lanes not understanding that they had to continue on the HOT lanes to a designated exit point. A number of crashes occurred after drivers attempted to exit the express lanes midstream by going through the flexible plastic pole barrier (express lane markers). However, in time, and with a continuous information campaign, fewer incidents occurred once the driving public became familiar with how the toll lanes work. Later surveys conducted by the DOT showed that the public was fairly receptive to the I-95 express lanes, prompting the FDOT to consider other express lane locations throughout the District.

10.1.4.2 Lessons Learned

One lesson learned was the importance of ITS for these types of projects. The ultimate goal is to have a working system, and having Operations involved during the planning and design phases ensures that ITS needs are met for the project to be successful.

Underestimating software development efforts was another lesson learned. New systems, such as managed toll lanes used in this project, require enough time and resources in place to develop the software needed to support operations.

The TSM&O strategy of ramp metering was also implemented to help manage the freeway during peak congestion. Prior to the I-95 express lane project, ramp meters had been installed at number of locations. However, FDOT decided to postpone activation of the meters until the new express lanes were opened. Several years later, when the ramp meters were turned on, it was discovered that the technology and software used in the meters was incompatible with the newer

system. Changes to ramp meters in the field, as well as changes to meter software were both required to integrate the two systems.

Due to the complexity and fast pace of the project, a single designated project manager (PM), referred to as a “Super PM”, was appointed to oversee every aspect of the project, from design, construction, and operations. The Super PM coordinated with project managers from each discipline, and had the authority to make final decisions on what needed to happen on the project. This helped to avoid conflicts and eliminate roadblocks between the different units, as well as fast track the process.

10.1.5 I-4 Express Lanes (District 5)

District 5 is implementing the TSM&O strategy of HOT lanes along I-4 as part of a massive 21 mile improvement/reconstruction effort called the “I-4 Ultimate” project that extends from west of Kirkman Road (SR 435) in Orange County to east of SR 434 in Seminole County, as shown in Figure 10.5. Funded through a Public-Private Partnership (P3), the completed project will contain two dynamic toll lanes in each direction, separated from the general-use lanes by a concrete barrier, and scheduled to be opened to the public by 2021.

The express lanes have been a consideration for over fifteen years, starting out as designated special-use lanes. FDOT initially envisioned the lanes would be dedicated connected vehicle automated vehicle (CVAV) lanes. As the design phase progressed over a 10-year period, the special-use lanes became HOT lanes. Because the project involved an ITS component at conception, Operations staff in the District were involved at all stages of the project development process – planning, PD&E, design, and currently, the construction phase.

10.1.5.1 Project Challenges

Contract development for the project was a significant challenge, primarily due to lack of understanding about TSM&O elements and how the contract requirements should come together. Those developing the contract, not experienced with Operations and Maintenance (O&M), did not recognize that the O&M section should include requirements related to TSM&O, even though there were O&M funds dedicated to TSM&O activities. The typical thought process concerning Maintenance related only to roadway elements, such as pavement or static signage, and that elements related to IT were the responsibility of others. Still today, maintaining ITS or TSM&O features are generally not included in what many consider to be Maintenance.

Difficulties were also experienced with finding consultant support in preparing contract requirements. Another related challenge resulted from trying to help FDOT lawyers better understand TSM&O/ITS activities so that they could appropriately evaluate and work to mitigate FDOT’s risk.

10.1.5.2 Lessons Learned

At the time the I-4 express lanes were in design, guidelines for this TSM&O strategy did not exist. Resources such as the *Express Lane Handbook* would have been useful. Going forward, having guidelines for other TSM&O strategies would be helpful.



Figure 10.5: I-4 Ultimate Improvement Project Location map
Source: www.i4ultimate.com

10.2 Difficulties with TSM&O Implementation

The following subsections summarize projects where implementing TSM&O strategies faced challenges. The information provided was gathered from interviews with TSM&O, ITS and Traffic Operations project managers that participated in the districtwide survey discussed in Chapter 4. The examples mentioned offer lessons learned on projects where TSM&O implementation opportunities were not realized.

10.2.1 District 2

An auxiliary lane project was proposed to mitigate congestion along several sections of I-295, south of downtown Jacksonville. District 2 TSM&O staff suggested extending the lane for traffic exiting I-295 to I-95 northbound to provide for better systems management in the future. Late in the design phase, there was a shift by planning staff and the consultant to build new express lanes on these sections to meet demand 20 years out. Since speed data indicated that travel speeds were 50-65 mph, even during peak hours, TSM&O recommended going forward with the auxiliary lanes, and possibly consider implementing ITS at a later time in preparation for CVAV. A no-build on the express lanes also was recommended by FHWA.

At the time decisions were being made, the TSM&O program in the District was in its infancy, and planning staff were not familiar with TSM&O strategies in general, or CVAV applications. The express lanes are currently under construction, and a bottleneck has developed at the I-95 northbound exit off I-295. This project highlights the need for better understanding of TSM&O by staff in other disciplines, outside of O&M, as well as how not including TSM&O staff in the decision-making process can greatly affect the outcome of a project.

10.2.2 District 5

In District 5, a corridor study to find the best solution for congestion on US Highway 27 (US-27) in Lake County was completed, resulting in the determination not to widen the existing roadway or build an alternate corridor, but rather to improve the capacity on the existing facility. Future growth in the area was expected to be minimal, and irregular demand was occurring on the roadway. Therefore, applying adaptive signal control was selected as the preferred solution.

When FDOT decided to add the design and construction of the project to the Work Program, District 5 Traffic Operations office was asked to begin the design of the system. For an adaptive signal control system to work properly, network support and someone who understands how the system works and how to operate it is needed. However, when Operations asked who was going to operate the system, DOT planning staff were under the impression that the system would run itself.

Although the County typically manages the operations and maintenance on the corridor, at the time County officials believed that they did not have the personnel or expertise to operate the system and decided not to fund the project. It was later determined that the County does have a network person on staff. In this case, as with many local agencies, the different disciplines generally work at different locations and have little contact with each other.

This missed opportunity primarily resulted from O&M not being considered or budgeted during the planning phase – the DOT corridor study. From this experience, the traffic operations group recognized that better communication with the planning group is needed to avoid future mishaps. The two groups now have weekly meetings to talk through projects to understand needs, learn what each other does, and to determine what role each will have in a project.

10.2.3 District 6

A missed TSM&O opportunity in District 6 occurred on Alton Road (Hwy A1A) in the City of Miami Beach. A full reconstruction of the south end of roadway, near South Beach, has been completed, with the northern section underway. The South Beach area contains a number of parking garages managed by the City of Miami Beach. The missed opportunity was realized when City was developing their ITS and parking management system and noted that the communication infrastructure could have been installed during the reconstruction of the roadway. To avoid this situation from happening again, DOT is working more closely with the City, and plans to install fiber optic during construction of the northern portion of Alton Road. This example underscores how communication with local agencies can provide opportunities to implement TSM&O strategies that can benefit both State and local jurisdictions.

10.2.4 Florida Turnpike (FTE)

At several locations along the Turnpike, adaptive signal control on connecting arterial facilities would improve operations and reduce the likelihood for exit ramp traffic to back-up along the 70 mph Turnpike facility. Demand is often difficult to manage during peak hours as many of the interchanges are already overloaded. While FTE works with local agencies to accomplish improvements, complications have resulted in coordinating with agencies at the right time for the local agency to acquire funding. In some cases, the agency is receptive to adaptive signal control, but does not want to add it to a project already underway, even though FTE may fund the installation.

The Turnpike traverses many jurisdictions, and working with local agencies can be challenging in that each agency operates differently. Many local agencies are receptive and proactive in implementing TSM&O strategies. In some cases, agencies engage the FTE to discuss potential improvements, while in other cases, FTE reaches out to them. Nevertheless, if everything is not lined up at the local level, FTE has to find a way to get the work done.

10.3 Other TSM&O Efforts

Project managers that did not list a specific project in the District survey were also interviewed to share details about TSM&O activities and the state-of-the-practice of TSM&O in their District. The following subsections summarize their comments.

10.3.1 District 1

In District 1, TSM&O involvement begins in the design phase starting with a review of each new stage one Scope of Services for design, where it can be determined if existing infrastructure is impacted or needs replacement, or additional ITS infrastructure should be requested. This process began in 2009 after project setbacks occurred when existing ITS infrastructure was not realized during the design phase, resulting in costly redesign efforts or supplemental agreements. The design office now includes TSM&O in the review process using the Electronic Review

Comments (ERC) system, along with other offices, such as Environmental and Right-of-way. Requirements for ITS analysis and plans development is also now included in the FDOT's standard Scope.

TSM&O involvement continues in the utility phase (Phase 2 Revised), with utility conferences, and when there are conflicts involved. The majority of ITS projects in the District are Design-Build projects, so project managers are comfortable using this type of project delivery method. The SE process is typically followed for most ITS projects, with documentation updated as needed after discussions with TSM&O management, office staff, and local agencies to see what their vision is as well.

A common issue experienced on ITS projects in the District is damage to existing fiber lines during construction. However, contractors are becoming more aware of the complexities of replacing and restoring components to their previous condition as they experience more projects with existing systems in place. Another issue occasionally experienced is the integration of new devices into the existing system, especially if the contractor or subcontractor is not familiar with specialized components. There are also vendor specific differences with each product type that may lead to potential issues.

After setbacks, with additional costs and project delays in earlier years, TSM&O project managers have worked to build closer relationships among the different disciplines in the District. Lessons learned are reviewed with all applicable stakeholders after every construction project to find ways to improve processes going forward. Understanding the expectations of each stakeholder encourages better results. District leadership is also supportive, fostering a team attitude that inspires project managers throughout the District to help each other out and work together.

District 1 is at the beginning stages of TSM&O consideration during the planning phase of the project development process. Until recently, TSM&O concepts and strategies have originated in the District's TSM&O office. To change the culture, TSM&O staff have started an outreach initiative to other offices to explain what TSM&O is and how TSM&O consideration during planning may impact the different disciplines. These efforts have already been successful with the planning office now beginning to engage the TSM&O project managers. TSM&O staff also received positive feedback at a recent meeting with the ISD office where project managers involved with transit, environmental, systems planning, rail, as well as an MPO liaison, were in attendance. The District is also planning in-house workshops in the near future focused on mainstreaming TSM&O in the planning process on a regular basis.

10.3.2 District 4

Most of the TSM&O projects implemented in District 4 have originated from the District's Traffic Operations office. Each year, the District Secretary and District Executive team conduct a project meeting where project managers are allowed to pitch new projects for funding. Once

approved, the Design office partners with Traffic Operations to develop the RFP requirements and contract documents. The majority of arterial ITS projects were funded through this process. Outside of express lane projects, Central office is typically not involved in the process. As of yet, projects with TSM&O consideration during the planning phase have not occurred in the District. However, leadership is promoting a more traditional approach be followed for future projects, with TSM&O consideration and concepts developed from planning and PD&E studies, and progress through the traditional project development process.

Primary issues experienced on ITS projects in the District result from repairs or replacement of system components after a project has been accepted. In some cases, the Traffic Operations office has had to accept a project even though RFP requirements have not been met. Not only have functional issues been experienced with newly constructed systems, but also safety issues have arisen such as electrical components not installed properly or power surges not being properly managed. Although TSM&O project managers are involved throughout the construction phase and engage construction project managers, the Construction office ultimately must ensure that the RFP requirements developed by the Design office are implemented. Construction office staff may possess only a general knowledge of systems, ITS, or TSM&O. Likewise, TSM&O project managers have limited knowledge of design and construction procedures and processes.

While the Design office works closely with Traffic Operations to develop the design and technical requirements for an RFP, the Construction office is typically not involved in this process. Since the District follows the waterfall method, each discipline hands off the project to the next discipline once their respective phase has been completed. When Construction hands off a project to Traffic Operations, project managers have little to no recourse but to accept the project, leaving the District with having to pay for repairs or replacement costs out of the Maintenance budget.

CEIs are generally required to send a list of lessons learned to the Design office following each project. However, based on the number of recurrent issues the District is experiencing, this process has had little impact on improvements. The result is a considerable amount of time spent by TSM&O project managers on construction issues.

Available right-of-way for roadway expansion is extremely limited in District 4. In recent years, the number of transit projects have increased. A disconnect has also been realized in that many people involved in these projects do not view transit ITS projects as TSM&O projects. Therefore, TSM&O staff are generally not involved, and the SE process is not followed as it would be on other ITS projects. Efforts by TSM&O project managers to improve communications with Transit staff in currently underway to address this gap.

10.3.3 District 6

District 6 TSM&O staff realize that in many cases FDOT cannot implement TSM&O strategies alone. The County (Miami-Dade) operates all of the traffic signals (over 3,000 signals), and the

transit system, so DOT should be a facilitator and support the needs of the County, if possible. District 6 TSM&O staff are also working with the Miami-Dade TPO to ensure that they are in the loop as well.

For other projects, District TSM&O staff members are engaging the stakeholders, the transit agencies and traffic signal operators, early in the planning stage to find out what kind of needs they may have in the future. Knowing this information, DOT can install the infrastructure during a DOT project to support the needs identified by the various agencies. The District has received good feedback from this process.

10.4 Chapter Summary and Discussion

Projects throughout the State that may serve as case studies for successful and unsuccessful TSM&O implementation were explored. TSM&O, ITS, and Traffic Operations project managers in each district, including the FTE, were contacted to share information on projects in their district where TSM&O strategies were identified and implemented early in the project development process. Both successful elements and challenges experienced during the course of each project were discussed. Project managers were also asked to share missed opportunities where TSM&O strategies could have provided a viable solution.

The projects discussed in this chapter originated from a districtwide survey conducted in July 2016 (see Chapter 4) to explore the current state-of-the-practice of TSM&O procedures and practices at the District level in the FDOT. In the survey, participating project managers were asked to list examples where TSM&O strategies were successfully implemented within the project development process, as well as examples of missed opportunities to deploy TSM&O strategies. Survey participants that did not list an example project in the survey were also interviewed to discuss details about TSM&O activities and the state-of-the-practice of TSM&O in their District.

Overall, the discussions reveal that the FDOT is steadily gaining in TSM&O implementation efforts statewide. However, based on the interviews and information gathered, there are a number of areas to improve upon. Key findings include:

- Communication among District and Central Office TSM&O staff can be instrumental in avoiding undesired project outcomes.
- The project delivery method and procurement method selected for TSM&O projects can greatly affect the outcome of the project.
- Coordination between the different disciplines in FDOT and a better understanding of what each group needs, can promote better project outcomes.
- Since the burden of the operating and maintaining system components falls on O&M, unforeseen additional costs can impact the Maintenance budget considerably.

- Solutions need to be explored to find ways to minimize the outlay of District funds for costly repair and/or replacement of system components post-construction to avoid paying for the same work twice.
- Much of product knowledge has been gained through project experience over time, and by different TSM&O project managers. The sharing of this knowledge among all staff members associated with the TSM&O program would be beneficial.
- Working with local agencies early in the project development process can lessen the outlay of agency funds with future deployments.
- A better understanding of ITS and TSM&O is particularly needed among CEI staff.

11 – RECOMMENDATIONS

This study explored the current state-of-the-practice of TSM&O in the FDOT to determine what would be required to mainstream TSM&O throughout the project development process. The objectives of this research effort included:

1. Conduct a comprehensive review aimed at providing recommendations that would facilitate revisions of the existing methods to better accommodate TSM&O in the project development process.
2. Explore and recommend alternative project development, procurement, and budgeting options for software-related ITS and TSM&O projects.

A comprehensive review of existing FDOT guidelines, two Districtwide surveys, and a review of projects, that may serve as case studies, where a TSM&O strategy was identified as the preferred alternative or solution to address a capacity or safety issue, were studied to determine the extent to which TSM&O is currently being incorporated in FDOT projects. An additional survey was also conducted to explore TSM&O best practices used by other state DOTs.

The objective of the guidelines review was to identify the degree to which TSM&O directives are included or referenced in the current FDOT procedural and design guidelines. The objective of the Districtwide surveys was to gather information on the current state-of-the-practice of TSM&O in each of the eight FDOT Districts, including the Florida Turnpike Enterprise (FTE). The first survey, was administered to project managers in the TSM&O, Intelligent Transportation Systems (ITS), and Traffic Operations groups in July 2016. The second survey, was administered in December 2016 to project managers and staff from other areas, such as design, planning, Project Development & Environment (PD&E), and construction. An additional survey was administered to DOT TSM&O, ITS, and Traffic Operations staff in each state in the U.S, including Florida, in April 2016, to explore best practices used in their TSM&O implementation methods.

Projects identified by project managers in the first Districtwide survey were also examined to serve as case studies to provide examples of TSM&O strategies deployed in Florida, as well as, challenges and lessons learned encountered during each project.

Project development, procurement, and budgeting options for TSM&O/ITS projects were also evaluated. As a first step, the existing project development processes were identified and documented. A survey was conducted to obtain information regarding specific challenges and shortfalls of the current project development process undertaken for district- and state-level ITS, ATMS, and TSM&O projects. The project managers for the OTM, ICMS, and MIMS projects were surveyed. Alternative project development approaches, including the Agile framework, were explored to see if they could be adopted for TSM&O/ITS projects.

This chapter briefly discusses findings from the aforementioned research tasks and offers suggested recommendations to facilitate the mainstreaming of TSM&O throughout the FDOT.

11.1 Project Development Process

Although project development is fairly consistent in the agency as a whole, procedural aspects vary among the Districts. Traditionally, the majority of TSM&O initiatives occur during the Operations and Maintenance (O&M) phase of the project development process. FDOT's goal of mainstreaming TSM&O seeks to integrate TSM&O statewide into each discipline in the process (Figure 11.1). The following sections present suggested recommendations to facilitate this goal.



Figure 11.1: TSM&O Integration Goal

11.1.1 Planning Phase

To effectively mainstream TSM&O throughout the project development process, TSM&O consideration must begin at the onset of a project, as it is being vetted for purpose and need. Key elements required for a successful integration of TSM&O into the planning phase include:

- Education and understanding of TSM&O
- Communication and coordination with TSM&O staff
- A formalized process and procedure
- Supportive language in FDOT guidelines

11.1.1.1 Education and Understanding of TSM&O

Statewide, project managers and staff outside of TSM&O, ITS, or Traffic Operations groups possess a limited knowledge and understanding of TSM&O in general. Providing planners and

planning staff with general information describing TSM&O, as well as examples of TSM&O strategies, could serve as an introduction and foundation for future TSM&O opportunities. Possible methods to provide general TSM&O information include:

- A short video on TSM&O
- An information flyer
- An example of TSM&O being successfully included in a project

11.1.1.2 Communication and Coordination with TSM&O Staff

Communication between Planning and TSM&O groups is essential to accomplish TSM&O mainstreaming goals. TSM&O staff should be involved when projects are first being evaluated for purpose and need. A designated TSM&O contact person can be established both at the District and Central office level to coordinate with planning staff. Input provided by the TSM&O contact may help to avoid missed TSM&O opportunities and future costly ad hoc projects. Participation of TSM&O program engineers in the SWAT team meetings is also suggested.

Suggested recommendations include:

- A designated TSM&O contact at the District level and Central office
- Regular communication between the two disciplines
- Participation in meetings and discussions related to project planning
- Participation in scoping of planning studies
- TSM&O program engineers' participation in SWAT team meetings

11.1.1.3 Formalized Process and Procedure

A formalized internal procedure is also needed that will promote engagement between TSM&O staff and other groups, and ensure TSM&O staff involvement during the planning phase of the project development process. A project development checklist, required for all projects being evaluated, is one way to accomplish this directive. The checklist document should be initiated during the planning phase, and follow the project through the sequential phases of development. The document should list the date of the initial meetings between TSM&O and planning staff and other disciplines, as well as list the name and contact information of project managers involved in the respective project.

Additionally, TSM&O staff should be included in the ETDM process, as well as the SWAT team to determine potential conflicts or opportunities relating to existing or planned TSM&O strategies in the vicinity of a new project.

In summary, suggested recommendations for a procedure to facilitate TSM&O involvement in the planning phase include:

- A project checklist documenting TSM&O inclusion as projects are being vetted
- TSM&O review opportunities in the ETDM

11.1.1.4 FDOT Planning Guidelines

It is understandable that numerous revisions to existing FDOT guidelines to include language relating to TSM&O may require considerable time and resources. Therefore, a more centralized approach may be advantageous, especially as the TSM&O program develops over time.

One suggestion is to focus procedural guidelines for including TSM&O in the project development process in the Project Management Handbook (PMH), Part II, Chapters 2 and 3, and reference the PMH in all other FDOT guidelines. A sample project development checklist mentioned in the previous section could be also be inserted in the PMH.

The PMH references the PD&E Manual as well as, Transportation Systems Management (TSM) and alternatives information. A suggested recommendation is to expand the TSM language and project management procedural information in the PMH, referencing the PD&E Manual for applicable federal and/or state funded projects.

In summary, suggested recommendations for FDOT guidelines pertaining to the planning phase include:

- Project management procedure revision to include TSM&O accompanied by a checklist to follow the project through the development process
- Expansion of TSM language

11.1.2 PD&E Phase

The Class of Action (COA) of a project determines whether the PD&E is needed. However, the majority of TSM&O projects are considered Programmatic Categorical Exclusions (PCEs), involving little to no environmental impacts often associated with capital projects, and therefore, do not require the PD&E process.

The current version of the PD&E Manual calls for TSM&O alternatives to be considered during the PD&E process. Additional language that references the PMH to ensure that TSM&O staff are involved in the process should be considered.

Recommended suggestions for PD&E phase guidelines include:

- Education for managers involved in PD&E to gain a better understanding of TSM&O
- TSM&O program engineers' participation in SWAT team meetings

11.1.3 Design Phase

Elements required to successfully mainstream TSM&O into the design phase of the project development process are similar to those needed for the planning and PD&E phases, and include:

- Education and understanding of TSM&O
- Communication and coordination with TSM&O staff
- A formalized process and procedure
- Supportive language in FDOT guidelines
- Participation by TSM&O staff in scoping and design phase reviews

11.1.3.1 Education and Understanding of TSM&O

Based on survey responses (Chapter 5), many Design project managers and staff have a considerably limited knowledge and understanding of TSM&O in general. An information campaign, discussed in Section 11.1.1 of this report, could serve to inform project managers and staff in FDOT's design groups.

Outside of TSM&O, ITS, and Traffic Operations groups, few design project managers understand or utilize the Systems Engineering (SE) process. Although several presentations are available on the FDOT website that cover the SE process, a more simplified publication explaining the process is suggested. Other disciplines may embrace the inclusion of TSM&O in their projects if a simplified explanation of what SE may offer is available.

11.1.3.2 Communication and Coordination with TSM&O Staff

TSM&O should be involved at the beginning of the design phase for each project, as applicable. Review of design elements with a TSM&O project manager, designated during the planning phase, promotes continued involvement of TSM&O in the development process and increases the likelihood of a successful project.

Coordination between the two disciplines will also further the knowledge and understanding of TSM&O strategies for design consultants. In addition, input provided by the TSM&O staff may influence design elements, potentially reducing future project costs.

11.1.3.3 Formalized Process and Procedure

A formalized internal procedure described in Section 11.1.1.3 of this report can be used when a project enters the design phase of the development process. The project development checklist, requiring TSM&O inclusion, initiated in the planning phase should follow a project through each subsequent phase. Following an initial meeting between TSM&O and design project managers, further involvement of TSM&O staff may be deemed unnecessary for projects that do not contain TSM&O or ITS elements.

11.1.3.4 FDOT Design Guidelines

The Practical Design Handbook provides guidance for practical designs based on safety and operational performance. The addition of TSM&O language to this document seems appropriate.

The remaining design guidelines published by FDOT do not contain language or references to TSM&O strategies or components. Revisions to the following documents should be considered, as deemed necessary, by FDOT:

- Computer Aided Design and Drafting (CADD) Manual
- Florida Greenbook
- Traffic Engineering Manual (TEM)
- Florida Design Manual (FDM) (publication in 2018)

11.1.4 Construction Phase

As with the planning and design phases of the project development process, elements required to successfully mainstream TSM&O into the construction phase include:

- Education and understanding of TSM&O
- Communication and coordination with TSM&O staff
- A formalized process and procedure

11.1.4.1 Education and Understanding of TSM&O

Based on research findings, considerable challenges have occurred in the construction phase of the project development process, often times resulting from deficient knowledge and experience with ITS infrastructure among industry contractors. A better understanding of ITS and TSM&O is particularly needed among Construction Engineering & Inspection (CEI) staff.

An outreach program, initiated by FDOT, may bridge the gap of knowledge that currently exists among construction staff members and contractors. A certification program to qualify potential contractors and inspectors would also be beneficial. An in-house TSM&O construction liaison position in each district could also be beneficial.

11.1.4.2 Communication and Coordination with TSM&O Staff

Communication and coordination between the CEI and TSM&O project manager is essential during the construction phase. In this phase, involvement of TSM&O staff may exceed the initial meeting suggested at the beginning of each phase. The process by which coordination and communication occurs can be determined at the District level.

11.1.4.3 Formalized Process and Procedure

The formalized internal procedure described in Section 11.1.1.3 of this report should follow through to the construction phase of each project. However, once construction is completed, the responsibility of maintaining and operating ITS components falls on the Operations group in each District. Based on research, TSM&O staff currently are viewed as a supportive role during the construction phase, rather than a distinct discipline, such as planning and design. By allowing TSM&O staff more input in accepting/rejecting the ITS work delivered by the contractor, future costly revisions and repairs could be avoided. This practice would also reflect the importance placed on the TSM&O program by the agency.

11.1.5 General Recommendations

11.1.5.1 Importance Placed on TSM&O

For TSM&O to become an integral element in the project development process, it will need to be viewed with equal importance to other disciplines. Because TSM&O strategies are unique to each project and may consist of complex solutions, project managers and staff in other disciplines should welcome the expertise of TSM&O staff members. Policy adopted by FDOT can serve to improve the current culture and cultivate more inclusive project management teams involving TSM&O.

11.1.5.2 Sharing of Knowledge

Much of the systems product knowledge has been gained through project experience over time, and by different TSM&O project managers. The sharing of this knowledge among all staff members associated with the TSM&O program would be beneficial. Biannual meetings of TSM&O project managers and staff from each District can facilitate this objective. Regular conference calls between District TSM&O, ITS, and Traffic Operations groups may also be advantageous.

11.1.5.3 TSM&O Culture

The culture of TSM&O needs to be improved at all levels within the agency. To improve the overall culture of TSM&O, a statewide information campaign that explains what TSM&O encompasses and FDOT's efforts to incorporate TSM&O in the project development process would be beneficial.

To minimize the cost to facilitate this effort, one suggestion is the development of a "Think TSM&O" informative video that explains the concept and goals of TSM&O strategies, offers examples of performance-based strategies that improve reliability and safety, and describes FDOT policies and directives geared at TSM&O inclusion in the project development process. The video should also include TSM&O success stories and clearly show how TSM&O fits into everything that the agency does and how it needs to be built into each project.

A TSM&O champion in each District, and at the Central office, can also serve as a contact person for questions. The video can also serve to inform the public and consultants about TSM&O and FDOT initiatives to mainstream TSM&O in Florida. An additional benefit of a “Think TSM&O” campaign may be realized with increased public support gained from media coverage highlighting the benefits of reliable travel times, motorist information, and improved incident management.

11.2 Different Development and Procurement Approaches for TSM&O Projects

The FDOT TSM&O Strategic Plan calls for enhanced goals to expedite the project development and delivery process. One of the initiatives is to consider the adoption of Agile project development methodologies. Transportation projects involving TSM&O/ITS strategies cannot be developed like traditional roadway projects, especially since the technologies involved can significantly change during the time between the initial conception to the final deployment. Although the desired end result is known, all the requirements may not be well defined at the beginning of the development process. In other words, some features and requirements that need to be addressed to meet the needs of the end users may not be clear at the onset. As such, traditional project development approaches (such as the Waterfall model) may not be suitable for TSM&O/ITS projects.

Agile methodology offers an alternative to the traditional approach, and is a faster paced approach that is more value-driven, change-oriented, and collaborative. Agile methodology adapts to changing requirements, encourages self-organizing teamwork and active participation of users, stakeholders, and customers, and ensures quick completion through a small time-boxed work flow. It is also commonly adopted for software development, and could potentially be adopted for TSM&O/ITS projects. Scrum, the most popular approach of Agile methodologies, consists of an iterative, incremental approach to optimize predictability and manage risk. As such, Agile methodology and the Scrum framework offer a potentially suitable alternative to the traditional project development approaches for TSM&O/ITS projects.

Moving forward, FDOT could consider adopting Agile philosophy for some TSM&O/ITS projects. The first step would be to determine if the project is a good candidate for using the Agile development method. Some projects may not be suitable for, or require, Agile principles, and the traditional Waterfall approach may suffice. TSM&O projects that are unique and creative, such as those pertaining to incident management and real-time traffic monitoring, may benefit more from using Agile principles and Scrum framework. However, transitioning from the traditional Waterfall approach to the Agile approach may be challenging. In-depth training on Agile framework can help to mitigate the transition difficulty for FDOT staff.

Both in-house and outsourced projects may benefit from using the Agile method. Additionally, Agile projects can be managed using a number of the commercially available software such as Jira, HP *Agile Manager*, etc.

Specific recommendations to consider include:

1. Provide training to the FDOT staff and stakeholders who may potentially be affected by adopting the Agile methodology. The training could focus on the organizational transformation, the need to transform to Agile principles, and the Agile framework.
2. Consider adopting the Agile project development process for ITS and TSM&O projects on a pilot basis, especially for the projects that are unique and creative. The functional specifications of the project should typically focus on *what* the system must do and not *how* the system does it. Instead of developing stringent project requirements, it is beneficial to treat the requirements as a guide, and have the design evolve over time.
3. For the majority of ITS and TSM&O projects, neither a pure Agile framework nor a traditional Waterfall approach is appropriate. Rather, a combination of the two methods may be required. The balance is typically based on the details provided in the functional requirements versus the requirements that are to be provided in the detailed design phase of the project.
4. Ensure that the end users of the system or product developed are directly engaged throughout the project development process. Feedback from the end users will better guide the design of the solution.
5. Document *Lessons Learned* and *Best Practices* in the project management process. The document should discuss successes and areas for improvements.

11.3 Alternative Development, Procurement, and Budgeting Options

The procurement of TSM&O/ITS projects often presents challenges for state and local transportation agencies. The traditional procurement approaches such as low-bid, etc., are more suited for traditional transportation projects with pre-defined requirements that generally use the Waterfall project development process. Procurement processes for software-related TSM&O/ITS projects can be more challenging when using traditional approaches, especially if the new Agile and Scrum frameworks are adopted. This section presents specific recommendations for FDOT to consider while procuring, budgeting, and developing software-related and non-software related TSM&O/ITS projects.

A majority of TSM&O/ITS projects are not entirely software-related, but often include hardware modifications and field devices. Nonetheless, almost all of these projects have at least minor software development/enhancement components. As such, TSM&O/ITS projects can be divided into two broad categories – software-related projects and non-software projects.

Software-related TSM&O/ITS projects may constitute:

- only the software component,
- both software and hardware components,
- primarily software and hardware components with some field devices, or

- primarily field devices with some hardware and some software modifications.

Non-software TSM&O/ITS projects may constitute:

- primarily hardware components with some field devices, or
- primarily field devices with some hardware modifications.

11.3.1 Software Development Projects

A practical approach in procuring software development projects is to have a *Proof of Concepts* first, followed by the entire development phase. In other words, Phase I (Proof of Concepts Phase) focuses on generating, revising, and finalizing all the system user interfaces and workflows, which generally capture all functionalities of the system. In this phase, a software company, for example, essentially works with FDOT on a limited budget to generate, review, and refine the workflows and all system user interfaces. This phase of the project does not require code development. Simple applications such as Photoshop or other currently available wire-framing tools could be used to very quickly construct a mock-up, or proof, of the user interface for review. This approach can be easily budgeted by FDOT as there is very little actual software development involved. This phase essentially uses the Agile process.

The next phase, Phase II, focuses on developing the actual product. FDOT may elect to develop a second Request for Proposal (RFP) for Phase II, if desired. For Phase II of the project, the companies will bid on the Concept of Operations (ConOps) to implement the designs finalized in Phase I. Since all of the information is already available from Phase I, the Agile approach, if adopted for Phase II, will only be used for minor refinements. The Waterfall model can also be adopted for Phase II.

For example, Phase I (Proof of Concepts Phase) could be completed in-house. FDOT staff and their District General Engineering Consultant (GEC) partners working in the Transportation Management Centers (TMCs) could use the Agile process to develop, review, and refine the workflows and system user interface needs. This can be accomplished through Task Work Orders to the GEC team to fit the needs of FDOT, and can also be expedited contractually. Once Phase I is completed, FDOT may elect to develop an RFP for Phase II.

11.3.2 TSM&O/ITS Projects with Minor Software-related Components

Almost all TSM&O/ITS projects have at least minor software development/enhancement components. Traditional project development and procurement processes may not be suitable for projects with software-related components. In such cases, the Waterfall approach could be adopted for non-software components, with Agile principles adopted for software-related components. Traditional procurement procedures are suitable for non-software components, while the two-phase approach discussed in Section 11.3.1 would be suitable for software-related components.

11.3.3 Non-software Related TSM&O/ITS Projects

The non-software projects do not require adoption of new and alternative project development, procurement, and budgeting approaches. For these types of projects, FDOT could continue to use the traditional Waterfall project development process, and the traditional procurement practices. However, if the agency foresees a need for additional flexibility in procuring hardware components, a two-phase approach, as discussed in Section 11.3.1, could be considered. Phase I could focus on identifying the equipment that is compatible; and Phase II could focus on purchasing and setting up the equipment.

11.4 Specific Recommendations

11.4.1 Project Development and Procurement Options

- Consider having two phases for any software development project, where Phase I (Proof of Concepts Phase) focuses on generating, revising, and finalizing all system user interfaces and the workflows, which generally capture all functionalities of the system. In this phase, a software company (or GEC staff, for example) essentially works with FDOT on a limited budget to generate, review, and refine the workflows and all system user interfaces. Phase II focuses on developing the actual product. FDOT may elect to develop a second RFP for Phase II, if desired. Since all of the information is already available from Phase I, the Agile approach, if adopted for Phase II, will only be used for minor refinements. The Waterfall model can also be used in Phase II.
- If the two-phase approach is to be adopted, FDOT staff and in-house GEC staff could work on Phase I (Proof of Concepts Phase) to develop the parameters, software user interfaces, and other requirements for the software update/development that is going to be procured. The Agile approach could be adopted for Phase I. Once Phase I is completed, Phase II could be procured using the more familiar and contract-friendly Waterfall approach.
- For non-software projects that have some software components, different approaches for procuring and developing non-software and software components are suggested. Consider the Waterfall project development process with traditional procurement methods for non-software components. On the other hand, consider the two-phase approach for procuring and developing the software components. Phase I (Proof of Concepts Phase) would focus on generating, revising, and finalizing all system user interfaces and workflows. This phase could use the Agile approach, while Phase II, that focuses on developing the actual product, could use the Waterfall approach.
- Use the Waterfall project development process for non-software projects. If additional flexibility is needed in procuring hardware components, a two-phase approach could be considered. Phase I would focus on identifying the equipment that is compatible; and Phase II would focus on purchasing and setting up the equipment.

- The RFPs and standard contract templates used by FDOT may need to be modified to accommodate the two-phase approach, and to provide flexibility for the FDOT project managers to be able to procure the latest equipment. The current approach used by FDOT attempts to specify everything upfront. This method can work if the specifications discuss *what* the system must do and not *how* the system must do it. Current FDOT specifications typically stress *how* the system must perform. Therefore, it is recommended that RFPs and standard contract templates be modified to focus on *what* the system must do rather than *how* the system should be designed. Additionally, it is recommended that contract templates continue to incorporate the following best practices:
 - Build acceptance testing into the contractual requirements. Clear expectations of what qualifies as acceptance and passing of the testing phase should be a part of the contract.
 - Build performance guarantees into the contract.
 - Build training and technical support into the contract.

11.4.2 Budgeting Options

- If high-level requirements are available and the framework is well-defined, an experienced software development firm can budget for it. Moreover, if a two-phase approach is used for a software development project, separate budgets can be allocated for each phase. Budgeting for Phase I (which uses Agile framework) can be relatively simple as it does not require code development. Once *Phase I* is completed, budgeting for Phase II can also be relatively simple since it will most likely follow the Waterfall model.

11.4.3 FDOT Staff Engagement

- For the end product to be successful, the end users of the system must be included in the development process. Feedback from the end users should help to guide the design of the solutions.
- It is not necessary for the FDOT project manager to be a software designer/engineer, as long as they are intimately familiar with the solution, and able to offer perspective.
- In any Agile process, the company building the software usually has all the necessary resources needed. The resource most needed by FDOT are the end users, and their input and opinions. In other words, end user involvement in the development process is paramount to a successful project.

11.5 Summary of Recommendations

A recent study was conducted to explore the current state-of-the-practice of TSM&O in the FDOT, and to determine what would be required to mainstream TSM&O throughout the project development process. The objectives of this research effort included:

1. Conduct a comprehensive review aimed at providing recommendations that would facilitate revisions of the existing methods to better accommodate TSM&O in the project development process.
2. Explore and recommend alternative project development, procurement, and budgeting options for software-related ITS and TSM&O projects.

The first objective was achieved through a comprehensive review of existing FDOT guidelines, two Districtwide surveys, and a review of projects where TSM&O strategies were implemented. The second objective was achieved through a survey of the project managers of current or recently completed TSM&O/ITS projects, a review of literature on alternative project development processes, and an interview with Mr. James Barbosa, Director, IBI Group (Florida) Inc. Suggested recommendations and proposed implementation methods are summarized in Table 11.1.

Based on research findings, successful mainstreaming of TSM&O will require TSM&O involvement in all phases of project development. Key elements needed to mainstream TSM&O in each discipline consists of:

- Provide education and understanding of TSM&O in all disciplines
- Require communication and coordination with TSM&O staff in all project phases
- Develop a formalized process and procedure for TSM&O inclusion
- Provide supportive TSM&O language in FDOT guidelines

Additional requirements for mainstreaming TSM&O include:

- Improve the overall culture of TSM&O in the FDOT
- Place greater importance on TSM&O through policy and procedure
- Encourage the sharing of knowledge of TSM&O strategies and products
- Develop an outreach program for potential contractors and inspectors
- Consider a certification program for CEI contractors
- Allow TSM&O staff more input with accepting or rejecting construction work

Suggested recommendations to consider while procuring, budgeting, and developing software-related ITS and TSM&O projects include:

- Consider adopting the Agile method for developing applicable TSM&O/ITS software projects.
- Consider a two-phase development process using the Agile approach for Phase I, and the Waterfall approach for Phase II.
- Include the end users of the system throughout the project development process.
- Incorporate TSM&O/ITS best practices into contract templates.
- Train applicable FDOT staff in Agile principles.

Table 11.1: Summary of Recommendations

Recommended Changes	Proposed Implementation Method
Improve the overall culture of TSM&O in the FDOT	Educational video, flyer, or in-house webinars
Provide education and understanding of TSM&O in all disciplines	Educational video, flyer, or in-house webinars
Require communication and coordination with TSM&O staff in all project phases	Regularly scheduled multi-disciplinary meetings
Encourage the sharing of knowledge of TSM&O strategies and products	Biannual statewide meetings of TSM&O staff
Improve contractor and inspector knowledge of TSM&O	Outreach program; certification program
ETDM Process	Include TSM&O program engineer in review process
Florida's ITS Integration Guidebook	Add language for coordination with the District TSM&O engineer
Project Development and Environment (PD&E) Manual	Include TSM&O program in the SWAT team
Project Management Handbook	Describe TSM&O; list TSM&O examples and potential issues
Traffic Engineering Manual (TEM)	Add general TSM&O and District contact information

The transportation industry is becoming more technologically advanced each year. With a strong commitment to developing the TSM&O program and placing a greater importance on TSM&O, implementation of suggested recommendations discussed in this memorandum can facilitate the effective mainstreaming of TSM&O throughout the FDOT project development process.

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APPENDIX A: District Survey I Questionnaire

District Survey I Questionnaire

Dear Participant:

Thank you for accepting our invitation to complete this survey!

The Florida Department of Transportation is conducting this survey to learn about how Transportation Systems Management and Operations (TSM&O) strategies, relating to roadway projects, are addressed in your district. TSM&O is defined by the Federal Highway Administration as the use of “integrated strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve the security, safety, and reliability of the transportation system.” Management and Operations (M&O) efforts vary across transportation modes, and include:

- Traffic Incident Management
- Traffic detection and surveillance
- Corridor, freeway, and arterial management
- Active transportation and demand management
- Work zone management
- Road weather management
- Emergency management
- Traveler information services
- Congestion pricing
- Parking management
- Automated enforcement Traffic control
- Commercial vehicle operations
- Freight management
- Coordination of highway, rail, transit, bicycle, and pedestrian operations

We estimate that it will take you less than 20 minutes to complete this survey. If you have any questions or comments about this survey, please contact:

Dr. Raj Ponnaluri, P.E., PTOE
State Arterial Management Systems Engineer
Florida Department of Transportation
(850) 410-5616
raj.ponnaluri@dot.state.fl.us

1. Please list your FDOT District number.

2. Please provide your information below:

Name:

Title:

Agency:

Address:

Phone:

Email:

3. When is TSM&O (includes ITS) considered in the project development process in your District? *Select all that apply.*

- Planning
- Design
- Construction
- Operations
- None
- Not sure

4. Many of the questions in this survey refer to “TSM&O Officials”. What office do you consider TSM&O officials to be located in? *Select all that apply.*

- Central Office
- District Office
- Not Sure

5. What group do you consider TSM&O officials to work in? *Select all that apply.*

- Traffic Operations group
- ITS group (within Traffic Operations)
- Planning group
- Not sure
- Other, please explain:

6. Do planning officials engage TSM&O officials in your District? If yes, please explain the process.

- Yes
- No
- Not sure

- If yes, process:



7. How closely do planning officials work with TSM&O officials in your District?

- Not at all
- Very little
- Somewhat
- Always

8. Do PD&E officials engage TSM&O officials in your District? If yes, please explain the process.

- Yes
- No
- Not sure
- If yes, process:

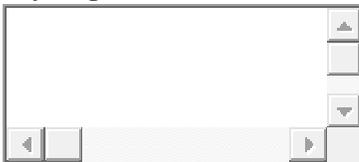


9. How closely do PD&E officials work with TSM&O officials in your District?

- Not at all
- Very little
- Somewhat
- Always

10. Do design officials engage TSM&O officials in your District? If yes, please explain the process.

- Yes
- No
- Not sure
- If yes, process:



11. How closely do design officials work with TSM&O officials in your District?

- Not at all
- Very little

- Somewhat
- Always

12. How closely do construction officials work with TSM&O officials in your District?

- Not at all
- Very little
- Somewhat
- Always

13. Do TSM&O officials review potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase?

- Yes
- No
- Not sure
- Other, please elaborate:



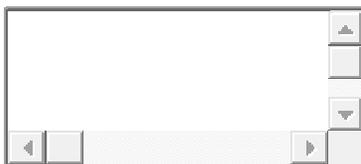
14. How often are TSM&O officials involved in project development process?

- Never
- Rarely
- Sometimes
- Often
- Always

15. How often are traffic operations engineers involved in project development process?

- Never
- Rarely
- Sometimes
- Often
- Always

16. What constraints have you encountered when proposing TSM&O strategies during the project development process?



17. Do you adopt the traditional project development process used for most civil engineering projects for TSM&O projects as well?



18. If not, please explain the project development process for TSM&O projects (including ITS and Advanced Traffic Management System (ATMS) projects).



19. How do you work toward reducing and eliminating delays in the project development and delivery process?



20. Have you observed confusion or misunderstanding about TSM&O among others you have worked with, either in the Department or private sector?

- Yes
- No
- Not sure
- Other, please elaborate:



21. Have you experienced difficulties in executing TSM&O contracts? If yes, please describe your experiences.

- Yes
- No
- Not sure

- If yes, please elaborate:



22. Is there a project that you were involved in where a TSM&O strategy may have been a more cost effective solution over the conventional capacity expansion method? If yes, please describe the project.

- Yes
- No
- Not sure
- If yes, please elaborate:



23. Is there a TSM&O (includes ITS) champion in your District?

- Yes
- No
- Not sure

24. What is the rank and title of the top TSM&O official within your District?

Rank

Title

25. When developing roadway projects, i.e., widening, resurfacing, interstate safety improvements, etc., do TSM&O or ITS officials get involved?

- Yes
- No
- Sometimes
- Not sure

26. What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?

27. What are some of the challenges that you have experienced during the construction phase regarding TSM&O components?

28. Please list all Department procedural guidelines that you believe should contain TSM&O language.

29. Please provide a success story where TSM&O strategies were successfully implemented within the project development process.

The following questions focus on the project delivery systems, procurement practices, contract management methods, and funding sources pertaining to TSM&O and ITS projects.

30. Project Delivery Systems: These refer to the overall processes by which a project is designed, constructed, and/or maintained). *Please list example project types for all the project delivery systems currently being used by your agency. Please hover over the options for more information.*

Design-Build:

Design-Bid-Build:

Design Sequencing:

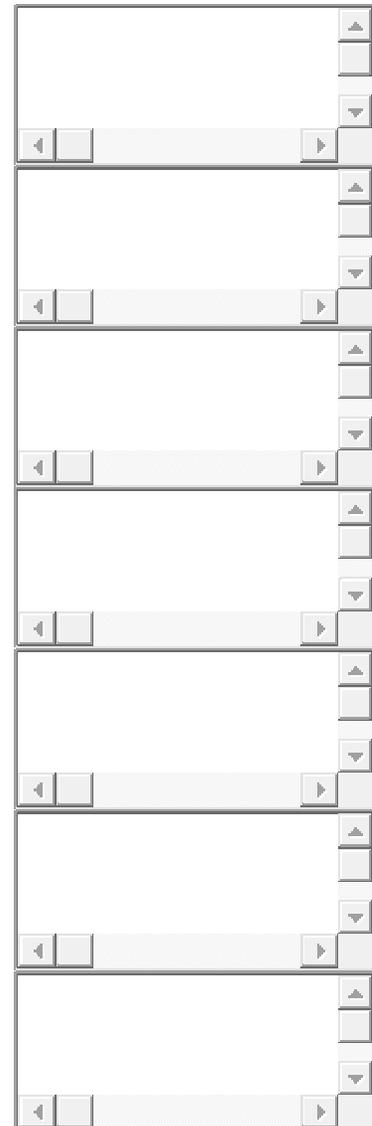
Indefinite Delivery/Indefinite Quantity (ID/IQ):

Agency-Construction Manager:

Construction Manager at-Risk:

Contract Maintenance:

Other (please elaborate):



31. If your agency uses Design-Build project delivery system, does it include any of the following: *Select all that apply.*

- Design-Build-Warranty
- Design-Build-Maintain
- Design-Build-Operate
- Design-Build-Operate-Maintain
- We don't use Design-Build system
- Not sure

32. Which project delivery system do you think is best for TSM&O (and ITS) projects? Why?

- Design-Build:

- Design-Bid-Build:
- Design Sequencing:
- ID/IQ:
- Agency-Construction Manager:
- Construction Manager at-Risk:
- Contract Maintenance:
- Other:
- Not Sure

33. Procurement Practices: These are the procedures agencies use to evaluate and select designers, contractors, and various consultants. *Please list example project types for all the procurement practices currently being used by your agency. Please hover over the options for more information.*

Cost-Plus-Time Bidding (A+B):

Multi-Parameter Bidding (A+B+C):

Lump Sum Bidding:

Alternate Design:

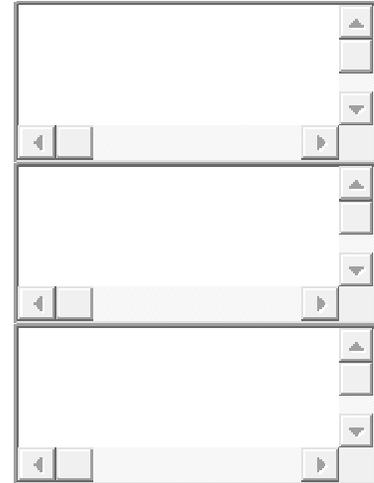
Alternate Bid:

Additive Alternates:

Best-Value Procurement:

Bid Averaging:

Other (please elaborate):



34. Which procurement method do you think is best for TSM&O (and ITS) projects? Why?

- Cost-Plus-Time Bidding (A+B):
- Multi-Parameter Bidding (A+B+C):
- Lump Sum Bidding:
- Alternate Design:
- Alternate Bid:
- Additive Alternates:
- Best-Value Procurement:
- Bid Averaging:
- Other (please elaborate):
- Not Sure

35. Contract Management Methods: These refer to the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. *Please list example project types for all the contract management methods currently being used by your agency. Please hover over the options for more information.*

Incentives/Disincentives (I/D) Provisions for Early Completion:



Lane Rental:

Flexible Notice to Proceed Dates:

Liquidated Savings:

Active Management Payment Mechanism (AMPM):

No Excuse Incentives:

Other (please elaborate):

36. Which contract management method do you think is best for TSM&O (and ITS) projects?
Why?

- I/D Provisions for Early Completion:
- Lane Rental:
- Flexible Notice to Proceed Dates:
- Liquidated Savings:
- Active Management Payment Mechanism (AMPM):
- No Excuse Incentives:
- Other (please elaborate):
- Not Sure

37. What funding sources are used for TSM&O activities by your District? *Select all that apply.*

- Congestion Mitigation and Air Quality Improvement (CMAQ) Program
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- National Highway Performance Program (NHPP)
- Transportation Investment Generating Economic Recovery (TIGER)
- Highway User Revenue Fund
- Local Taxes
- Unified Planning Work Program (UPWP)
- Public-Private Partnership
- Other, please specify:

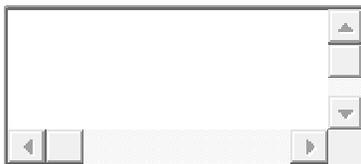
38. Please identify the strategies used by your District to fund TSM&O projects.

- We set aside dedicated funding for TSM&O projects
- We allow TSM&O projects to compete with other types of projects for funding
- We combine a set-aside with the ability for TSM&O projects to compete for other funding
- Other, please specify:

39. Which system development strategy (i.e., model) does your District adopt for TSM&O and ITS projects. *Select all that apply. Please hover over the options for more information.*

- Waterfall Model
- Agile Model
- Incremental Build Model
- Spiral Model
- Other, please specify:

40. What challenges, if any, are you currently encountering with the system development model that you have adopted for TSM&O and ITS projects?



We thank you for your time spent taking this survey.

Your response has been recorded.

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APPENDIX B: District Survey I – Part I Responses

Table B.1: TSM&O in the Project Development Process

District	Title of Participant	When is TSM&O (includes ITS) considered in the project development process in your District?					
		Planning	Design	Construction	Operations	None	Not sure
1	FMS/AMS Specialist IV		X	X	X		
2	TSM&O Program Manager	X	X		X		
3	TSMO Project Engineer				X		
4	District TSM&O Engineer	X	X	X	X		
	Freeway Operations Manager	<i>No Answer</i>					
	District 4 LCIS Administrator				X		
	ITS Ops Manager		X				
5	TSMO Engineer Freeways	X	X				
6	TSM&O Program Engineer	X	X	X	X		
7	ITS Program Manager	X	X	X	X		
Turnpike	Traffic Services Engineer	X	X		X		

Table B.2: Office and Work Group of TSM&O Staff

District	Title of Participant	Many of the questions in this survey refer to “TSM&O Officials”. What office do you consider TSM&O officials to be located in? Select all that apply.			What group do you consider TSM&O officials to work in? Select all that apply.				
		Central Office	District Office	Not sure	Traffic Operations group	ITS group (within Traffic Operations)	Planning group	Not sure	Other
1	FMS/AMS Specialist IV	X	X		X	X			
2	TSM&O Program Manager	X	X		X	X			
3	TSMO Project Engineer	X	X		X	X			
4	District TSM&O Engineer		X			X			
	Freeway Operations Manager	X				X			
	District 4 LCIS Administrator	X			X	X			
	ITS Ops Manager	X	X		X	X			
5	TSMO Engineer Freeways	X	X		X	X	X		A
6	TSM&O Program Engineer	X	X			X	X		
7	ITS Program Manager	X	X		X	X	X		B
Turnpike	Traffic Services Engineer	X	X		X	X	X		

A: Executive Management

B: Production Department and Construction Department

Table B.3: Interaction with Planning and PD&E Staff

District	Title of Participant	Do planning officials engage TSM&O officials in your District? If yes, please explain the process.				How closely do planning officials work with TSM&O officials in your District?				Do PD&E officials engage TSM&O officials in your District? If yes, please explain the process.				How closely do PD&E officials work with TSM&O officials in your District?			
		Yes	No	Not Sure	Process	Not at all	Very little	Some-what	Always	Yes	No	Not Sure	Process	Not at all	Very little	Some-what	Always
1	FMS/AMS Specialist IV		X				X				X				X		
2	TSM&O Program Manager	X			A			X		X		H				X	
3	TSMO Project Engineer	X			B		X					X			X		
4	District TSM&O Engineer	X			C			X		X		I				X	
	Freeway Operations Manager	No Answer					X					X			X		
	District 4 LCIS Administrator	No Answer					X			X		J			X		
	ITS Ops Manager	No Answer					X			X		K				X	
5	TSMO Engineer Freeways	X			D				X	X		L				X	
6	TSM&O Program Engineer	X			E			X		X		M				X	
7	ITS Program Manager	X			F		X			X		N			X		
Turnpike	Traffic Services Engineer	X			G				X			X			X		

Table B.3: Interaction with Planning and PD&E Staff (continued)

- A: They come to me with questions for larger sized projects with limited budget.
- B: Not an official process yet established.
- C: TSM&O officials are asked to review long range plans for input on TSM&O solutions. Smaller studies, the involvement of TSM&O staff is inconsistent. Design will work with TSM&O officials if there is an ITS component. However, the level of engagement of TSM&O staff is not consistent from project manager to project manager.
- D: We meet minimally weekly. We call in each other for assistance in our project development process.
- E: Recently, the ITS Office has been engaged in a few planning studies. But there is no establish process (project-by-project basis).
- F: During the scope development, all are invited to the meeting.
- G: Meet on a regular basis as a Turnpike TSM&O Task Team to review projects, initiatives, and future goals related to TSM&O.
- H: They meet with us for Express Lanes and traffic issues that have limited funds to resolve through capacity.
- I: As reviewers.
- J: We are invited to kick off meetings.
- K: Informally.
- L: Negotiations, ConOps Review, ConOps development.
- M: There is no formal process. For Express Lanes projects, TSM&O representatives are engaged - Reviewing and supporting Systems Engineering Management Plan and ConOps development.
- N: During scope development all are invited to participate.

Table B.4: Interaction with Design and Construction Staff

District	Title of Participant	Do design officials engage TSM&O officials in your District? If yes, please explain the process.				How closely do design officials work with TSM&O officials in your District?				How closely do construction officials work with TSM&O officials in your District?			
		Yes	No	Not Sure	Process	Not at all	Very little	Somewhat	Always	Not at all	Very little	Somewhat	Always
1	FMS/AMS Specialist IV	X			A				X				X
2	TSM&O Program Manager	X			B			X			X		
3	TSMO Project Engineer			X			X				X		
4	District TSM&O Engineer	X			C			X				X	
	Freeway Operations Manager			X			X				X		
	District 4 LCIS Administrator	X			D		X				X		
	ITS Ops Manager	X			E			X		X			
5	TSMO Engineer Freeways	X			F			X					X
6	TSM&O Program Engineer	X			G			X					X
7	ITS Program Manager	X			H			X				X	
Turnpike	Traffic Services Engineer	X			I			X			X		

- A: Included in scope & staff hour development for new projects, phase submittal reviews (ERC).
- B: Mostly younger staff who think outside the box and older staff who have technology questions.
- C: Often as reviewers.
- D: During design we are contacted if the project is within our service area.
- E: Informally.
- F: Scoping, Negotiations, Plan Review, Technical Expertise as needed.
- G: There is no formal process. However, for Express Lanes related projects, there is close coordination between Design and TSM&O officials.
- H: During scope development.
- I: Discuss TSM&O alternatives, current and future Work Program projects, etc.

Table B.5: Involvement of TSM&O Staff and Traffic Operations Engineers

District	Title of Participant	Do TSM&O officials review potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase?				How often are TSM&O officials involved in project development process?					How often are traffic operations engineers involved in project development process?				
		Yes	No	Not Sure	Other	Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always
1	FMS/AMS Specialist IV		X				X						X		
2	TSM&O Program Manager		X				X					X			
3	TSMO Project Engineer			X			X						X		
4	District TSM&O Engineer				A			X					X		
	Freeway Operations Manager			X				X					X		
	District 4 LCIS Administrator		X				X							X	
	ITS Ops Manager			X			X					X			
5	TSMO Engineer Freeways				B					X				X	
6	TSM&O Program Engineer				C			X						X	
7	ITS Program Manager	X							X					X	
Turnpike	Traffic Services Engineer	X						X					X		

- A: TSM&O officials are not in the development division. The core functions of planning and design still resides in the development division. The TSM&O officials do periodically review upcoming projects for TSM&O opportunities but do not do this systematically.
- B: This is a no because of the "over" [wording of question]. We look for the right improvement based on purpose and need.
- C: At times, selected projects are reviewed by TSM&O representatives. There is no formal process.

Table B.6: TSM&O Constraints and Processes

District	Title of Participant	What constraints have you encountered when proposing TSM&O strategies during the project development process?	Do you adopt the traditional project development process used for most civil engineering projects for TSM&O projects as well?	If not, please explain the project development process for TSM&O projects (including ITS and Advanced Traffic Management System (ATMS) projects)	How do you work toward reducing and eliminating delays in the project development and delivery process?
1	FMS/AMS Specialist IV	Budget constraints can adversely affect the implementation of ITS strategies; don't know what is scoped until already in design scope development process	We utilize some of the traditional project development processes. We utilize the Systems Engineering process for ITS/TSM&O projects.	We utilize some of the traditional project development processes. We utilize the Systems Engineering process for ITS/TSM&O projects.	N/A
2	TSM&O Program Manager	TSM&O gets involved too late in the process. Usually a huge investment is already made by the Department prior to thinking of us, hence they move forward with limited consideration for using technology.	No, because technology changes so quickly. We have a hard time staying within the current 5 and 10 year process so we usually maintain 2 years.	We look at needs, examine existing and near term technology, then try to apply it to an upcoming project that is funded.	We rely on the TERL, the Innovative Product Listing and ITS Expo events to select the proper technology for our needs. We also often consider the System Engineering approach for procurement and delivery.
3	TSMO Project Engineer	Not yet established this process.	Not sure.		<i>No Answer</i>
4	District TSM&O Engineer	Project funding and scope. Project managers will either not have enough money programmed in the planning study, design project and/or the construction phase to include TSM&O components. Another large issue is O&M. There is not a clear understanding for how TSM&O project components are to be funded for O&M, specifically the arterials. There are some funding sources for O&M that can be used. This goes for state and federal funds. In District four, if there is not a clear funding source for O&M the TSM&O concept is not to go beyond the planning stage. The District is no longer funding O&M for TSM&O concepts using District Discretionary Dollars.	Yes, the traditional project development process is used by the design office. The design project managers are now managing ITS/TSM&O projects using this process and come to Traffic Ops/TSM&O experts for input/guidance. Guidance is needed on all steps, from scoping the design, reviewing the fee estimates for consultant support to what sort of deliverables they are to produce, reviewing those deliverables, etc. However, the level of involvement is really up to the project manager. Some are more engaged with traffic ops than others.		Reducing and eliminating delays is not the responsibility of the TSM&O unit, but the project manager of the project. We support the project management staff. If there is an issue of time that the project manager needs help with, we do our best to support them to shrink schedules. This is often done in construction. The final acceptance date in construction is a date that is often hard for contractors who are awarded ITS/TSM&O projects to meet.

Table B.6: TSM&O Constraints and Processes (continued)

District	Title of Participant	What constraints have you encountered when proposing TSM&O strategies during the project development process?	Do you adopt the traditional project development process used for most civil engineering projects for TSM&O projects as well?	If not, please explain the project development process for TSM&O projects (including ITS and Advanced Traffic Management System (ATMS) projects)	How do you work toward reducing and eliminating delays in the project development and delivery process?
4	Freeway Operations Manager	Have not had to do this step	Mostly		<i>No Answer</i>
	District 4 LCIS Administrator	Budget	Unsure		Just started process, not implemented yet.
	ITS Ops Manager	Not formally part of process.	Yes		I do not.
5	TSMO Engineer Freeways	Programming results in an expected outcome. Lack of technical expertise in consultants. There is a gap we are trying to bridge on who handles the project when a TSMO outcome is selected at Planning but programming has not occurred.	Yes. The machine was built to do it one way.	Different people do the majority of development, but follow the same process.	Follow the process. Plan ahead.
6	TSM&O Program Engineer	Lack of understanding among FDOT personnel.	We consider TSM&O elements to be part of civil engineering projects. Once systems are involved, System Engineering is adopted.		TSM&O Office serves as technical advisors/reviewers and supports other FDOT office during the project development and delivery process.
7	ITS Program Manager	<i>No Answer</i>	<i>No Answer</i>		<i>No Answer</i>
Turnpike	Traffic Services Engineer	Timeliness, project schedules, TSM&O strategies are a different approach and it takes time for others to get comfortable with their potential.	The traditional project development process is used for most projects; TSM&O projects are inserted into the process, where possible.		Yes, even though the project development and delivery process is fairly rigid and driven by schedule and achieving production results.

Table B.7: TSM&O Experiences

District	Title of Participant	Have you observed confusion or misunderstanding about TSM&O among others you have worked with, either in the Department or private sector?				Have you experienced difficulties in executing TSM&O contracts? If yes, please describe your experiences.				Is there a project that you were involved in where a TSM&O strategy may have been a more cost effective solution over the conventional capacity expansion method? If yes, please describe the project.			
		Yes	No	Not Sure	Other	Yes	No	Not Sure	Experiences	Yes	No	Not Sure	Description
1	FMS/AMS Specialist IV	X					X				X		
2	TSM&O Program Manager	X				X			A	X			H
3	TSMO Project Engineer	X				<i>No Answer</i>					X		
4	District TSM&O Engineer	X				X			B	<i>No Answer</i>			
	Freeway Operations Manager	X				<i>No Answer</i>					X		
	District 4 LCIS Administrator	X				X			C		X		
	ITS Ops Manager	X				X			D	<i>No Answer</i>			
5	TSMO Engineer Freeways	X				X			E	X			I
6	TSM&O Program Engineer	X				X			F	X			J
7	ITS Program Manager	<i>No Answer</i>				<i>No Answer</i>				<i>No Answer</i>			
Turnpike	Traffic Services Engineer	X				X			G	X			K

Table B.7: TSM&O Experiences (continued)

- A: Limited expertise internally and in the private industry involved with transportation projects. External industries like IT are excluded from the planning process.
- B: 1. not enough consultants are going after projects. In the last few procurements, there were only 2 bidders. 2. Same contractor gets the operations contract, not enough competition. The last time the freeway operations contract advertised, only 1 company bid.
- C: Lack of knowledge of ITS by other staff reviewing contracts. Contracts not geared for ITS.
- D: For instance, it is difficult to find specifications for how many cubic feet of network capacity can be required for TSM&O/ITS projects.
- E: Data contracts have run into challenges due to the ambiguity of the ROADS initiative. Also consultant rate negotiations have been a problem due to lack of categories.
- F: Lack of understanding of complexities with projects involving "systems" by FDOT personnel and others.
- G: Oftentimes, TSM&O projects are measured in terms of Benefit-Cost and assumed to only be in place for a few years, prior to capital improvements being made. Therefore, ROI is investigated and sometimes leads to the TSM&O project not being pursued.
- H: We recommended auxiliary lanes and an alternative TSM&O solutions but were denied because of Department policy. This led to a project that was very expensive and overdue on schedule. The TSM&O solution was about \$150 million dollars less expensive and could have been delivered three years earlier.
- I: US 27, use of Adaptive Signal Control.
- J: 95 Express, Palmetto Express - both of these projects added capacity but are primarily TSM&O projects. TSM&O strategies are heavily utilized to operate Express Lanes (congestion pricing, incident management, traveler information, etc.).
- K: Currently in the process of incorporating adaptive traffic signal control at an intersection in the hope of eliminating/reducing queuing on the exit ramp from the Turnpike. Capacity improvements will take a while to implement (two or more years).

Table B.8: TSM&O District Staff

District	Title of Participant	Is there a TSM&O (includes ITS) champion in your District?			What is the rank and title of the top TSM&O official within your District?		When developing roadway projects, i.e., widening, resurfacing, interstate safety improvements, etc., do TSM&O or ITS officials get involved?			
		Yes	No	Not Sure	Rank	Title	Yes	No	Sometimes	Not sure
1	FMS/AMS Specialist IV		X		Career Service	FMS/AMS Specialist IV			X	
2	TSM&O Program Manager	X			Assistant District Traffic Operations Engineer	TSM&O Program Manager			X	
3	TSMO Project Engineer	X			<i>No Answer</i>	DTOE	X			
4	District TSM&O Engineer			X	Assistant to a Cost Center Manager (DTOE)	TSM&O Program Engineer			X	
	Freeway Operations Manager	X			<i>No Answer</i>	TSM&O Program Manager			X	
	District 4 LCIS Administrator	X			<i>No Answer</i>	District TSM&O Engineer			X	
	ITS Ops Manager		X		<i>No Answer</i>	District TSM&O Engineer			X	
5	TSMO Engineer Freeways	X				Director of Production	X			
6	TSM&O Program Engineer	X			Executive/Director	Director of Transportation Operations			X	
7	ITS Program Manager	<i>No Answer</i>			<i>No Answer</i>	<i>No Answer</i>			X	
Turnpike	Traffic Services Engineer	X			Department Head	District Traffic Operations Engineer (DTOE)			X	

Table B.9: TSM&O Challenges and Guidelines

District	Title of Participant	What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?	What are some of the challenges that you have experienced during the construction phase regarding TSM&O components?	Please list all Department procedural guidelines that you believe should contain TSM&O language.	. Please provide a success story where TSM&O strategies were successfully implemented within the project development process.
1	FMS/AMS Specialist IV	Lack of planning office buy-in for TSM&O strategies.	None experienced.	Plans Preparation Manual, PD&E Manual	None experienced.
2	TSM&O Program Manager	Limited knowledge by many in the Department regarding TSM&O. Upper level management that is more comfortable with traditional transportation approach. Limited expertise in the industry to support TSM&O efforts.	There is little to no expertise in the private industry to support the deployment of TSM&O projects. This includes design firms, construction firms and engineering inspectors. Very few professionals for delivery of statewide deployment.	PPM, TEM, ITS Procedures	Philips Highway Integrated Corridor Management project where we incorporate ITS, Transit Signal Priority, Traffic Signal Preemption, traffic signal timing designs, arterial detour sign deployment and operational guidelines.
3	TSMO Project Engineer	It is not yet a culture in our district.	ITS is being classified as a utility and not as infrastructure.	All guidelines.	Pensacola Bridge Replacement

Table B.9: TSM&O Challenges and Guidelines (continued)

District	Title of Participant	What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?	What are some of the challenges that you have experienced during the construction phase regarding TSM&O components?	Please list all Department procedural guidelines that you believe should contain TSM&O language.	. Please provide a success story where TSM&O strategies were successfully implemented within the project development process.
4	District TSM&O Engineer	A resistance for project managers to include TSM&O deliverables and items. Assuming there is a budget for operations and maintenance (if there isn't then the project doesn't go anywhere) we have seen poor communication between planning, design and traffic ops resulting in systems being installed that can't communicate with the traffic management center or no integration of new systems with existing systems (such as ATMS with TSP). TSM&O is not treated like other elements, like drainage or structures.	TSM&O gets included in larger projects resulting in a small amount of the budget being for ITS/ATMS and the rest for physical improvements. This imbalance has then a roadway contractor overseeing ITS/ATMS subcontractors. The lack of understanding of how systems work and the processes for installing/integrating and testing has resulted in underbidding/underestimates from the contractor on how complex and time consuming the ITS/ATMS work is. Often tests are cut short, test results are submitted improperly, and schedule impacts occur. Local agencies and FDOT in house staff tend to do some of the work for the contractor to help the project move along. Since we are one DOT, we don't see this necessarily as a problem but it can be an issue if the contractor takes advantage of this assistance.	1. PD&E Manuals 2. Work Program Instructions (improved language) 3. Position descriptions in planning, design and construction (some positions should include ITS/TSM&O background requirements, expectations) 4. Procurement processes in general. For example, contractual service contracts vs. professional services contracts. TSM&O and ITS projects require engineers, but because a lot of the deliverables are not signed and sealed or the project is seen more of a labor type contract, they are procured through contractual services. The rules/limitations of contractual services contracts make it difficult to get (and keep) highly technical and experienced staff. 5. Qualification process for consultants and contractors. The process for getting and maintaining the qualifications should be made more rigorous. A company may be prequalified based on one person that works in the 100+ organization.	<i>No Answer</i>
4	Freeway Operations Manager	<i>No Answer</i>	<i>No Answer</i>	<i>No Answer</i>	<i>No Answer</i>

Table B.9: TSM&O Challenges and Guidelines (continued)

District	Title of Participant	What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?	What are some of the challenges that you have experienced during the construction phase regarding TSM&O components?	Please list all Department procedural guidelines that you believe should contain TSM&O language.	. Please provide a success story where TSM&O strategies were successfully implemented within the project development process.
4	District 4 LCIS Administrator	Designers who are not versed in DOT standards and specs.	Inspectors who do not realize the importance of meeting the design exactly.	<i>No Answer</i>	<i>No Answer</i>
4	ITS Ops Manager	TSM&O is, at its heart, the realm of the IT world. Civil Engineers are usually not well versed in the nature of larger scale complex IT infrastructure projects. The entire FDOT Work Program and project delivery process is designed for a "typical" RRR project, not large scale technology deployments.	IT and ITS are the absolute last priority once projects enter construction.	<i>No Answer</i>	<i>No Answer</i>
5	TSMO Engineer Freeways	Rates, incompetent consultants.	Incompetent CEI and very intelligent contractors.	All; Planning Guidance, Corridor Planning, Complete Streets, Design Manual, Design Handbooks, CPAM, Structures Design Manual, Project Manager Guidebook	Express Lanes are the easiest as they are the most integrated; I-4 Ultimate involved us from the beginning and accommodated our requirements

Table B.9: TSM&O Challenges and Guidelines (continued)

District	Title of Participant	What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?	What are some of the challenges that you have experienced during the construction phase regarding TSM&O components?	Please list all Department procedural guidelines that you believe should contain TSM&O language.	. Please provide a success story where TSM&O strategies were successfully implemented within the project development process.
6	TSM&O Program Engineer	Lack of understanding of TSM&O strategies and systems by FDOT personnel.	Systems are often overlooked and are left to the end of the project. At times, testing requirements are water down and projects are accepted prematurely. Construction Engineering Inspections lack of knowledge/inexperience with systems.	I believe that TSM&O language needs to be added to guidelines at all project development phases (planning, PD&E, and design). The level of detail will vary with accordance to the phase. One of the critical areas is related to identifying and programming funding for future operations and maintenance of the systems/TSM&O strategies under development. This should happen at the planning phase and refined as the projects moves to the other phases.	95 Express
7	ITS Program Manager	<i>No Answer</i>	<i>No Answer</i>	<i>No Answer</i>	<i>No Answer</i>
Turnpike	Traffic Services Engineer	Lack of time, resources, staffing, project development is schedule and production-driven ("how many projects can we let this year?", for example).	Lack of CEI knowledge, certain project delivery methods (i.e., Design-Build) do not always lend themselves to a good product, depending on how much thought and time was put into the RFP development process. TSM&O components are not well understood by construction as a whole - also, since TSM&O components are a relatively small part (in terms of dollars) to the overall project, these components have a tendency to be overlooked.	Project Management Handbook, PD&E Handbook, PPM, TPPPH (Turnpike document), etc.	Signing and Pavement Marking improvements to reduce crash occurrences at exit ramps where changing the geometry may be costly and take time to implement.

APPENDIX C: District Survey I – Part II Survey Responses

Table C.1: Project Delivery Systems

District	Title of Participant	Project Delivery Systems: These refer to the overall processes by which a project is designed, constructed, and/or maintained. Please list example project types for all the project delivery systems currently being used by your agency.							
		Design-Build	Design-Bid-Build	Design Sequencing	Indefinite Delivery/Indefinite Quantity (ID/IQ)	Agency-Construction Manager	Construction Manager at-Risk	Contract Maintenance	Other
1	FMS/AMS Specialist IV	A							
2	TSM&O Program Manager	B	F	N/A	N/A	N/A	G	H	K
3	TSMO Project Engineer	C							
4	District TSM&O Engineer	D	ATMS					I	L
	Freeway Operations Manager	<i>No Answer</i>							
	District 4 LCIS Administrator	<i>No Answer</i>							
	ITS Ops Manager	Vast majority							
5	TSMO Engineer Freeways	TPAS	TSP Phase 2, RTMC					CCTV Replacement	M
6	TSM&O Program Engineer	E	E					J	
7	ITS Program Manager	<i>No Answer</i>							
Turnpike	Traffic Services Engineer	Yes	Yes					Yes	

A: ASCT, ATMS, FMS, ATIS, IMS

B: ITS Deployment on I-95 that ended up over budget and late on schedule.

C: Pensacola Bridge Replacement

D: ATMS, ATCS, ITS, Express Lanes, Ramp Metering

Table C.1: Project Delivery Systems (continued)

E: Express lanes, ITS projects

F: ITS deployment on I-295 southwest that was at budget but late in schedule.

G: Used on the RTMC that limited design features and the final product that was delivered.

H: Done occasionally with success, however funding sources limit the opportunity for more usage.

I: ITS/ATMS maintenance

J: Systems operations, device repair/maintenance, incident management

K: System Manager whereby the design firm provides plans, the Department purchases equipment, contractor deploys infrastructure, design firm integrates with Department staff, and product is what is desired, on-time and under budget.

L: Asset Maintenance of a roadway - contract in D4 now includes Road Rangers

M: ITN: ICM; ITB: IT Hardware; DBOM SR 40 ASC

Table C.2: Design-Build Project Delivery System

District	Title of Participant	If your agency uses Design-Build project delivery system, does it include any of the following: Select all that apply.					
		Design-Build-Warranty	Design-Build-Maintain	Design-Build-Operate	Design-Build-Operate-Maintain	We don't use Design-Build systems	Not sure
1	FMS/AMS Specialist IV	X					
2	TSM&O Program Manager	X					
3	TSMO Project Engineer				X		
4	District TSM&O Engineer						X
	Freeway Operations Manager						X
	District 4 LCIS Administrator	X					X
	ITS Ops Manager		X		X		
5	TSMO Engineer Freeways	<i>No Answer</i>					
6	TSM&O Program Engineer	X			X		
7	ITS Program Manager	<i>No Answer</i>					
Turnpike	Traffic Services Engineer	X					

Table C.3: Preferred TSM&O and ITS Project Delivery System

District	Title of Participant	Which project delivery system do you think is best for TSM&O (and ITS) projects? Why?								
		Design-Build	Design-Bid-Build	Design Sequencing	ID/IQ	Agency-Construction Manager	Construction Manager at-Risk	Contract Maintenance	Other	Not sure
1	FMS/AMS Specialist IV	A								
2	TSM&O Program Manager								E	
3	TSMO Project Engineer								F	
4	District TSM&O Engineer									X
	Freeway Operations Manager									X
	District 4 LCIS Administrator									X
	ITS Ops Manager	B								
5	TSMO Engineer Freeways								G	
6	TSM&O Program Engineer		D							
7	ITS Program Manager	No Answer								
Turnpike	Traffic Services Engineer	C								

- A: Limited Department liability, puts all responsibility on the DB contractor, adjusted score grading makes the contractor propose qualified personnel and high quality construction concepts, often comes with extended warranties.
- B: If done correctly and executed as written it can be the most successful. However D/B projects will not have a TSM&O design PM nor a TSM&O construction PM. Department management decided that all offices should focus on core business. The practice of TSM&O personal as design PM was stopped.

Table C.3: Preferred TSM&O and ITS Project Delivery System (continued)

- C: Only if the project is a stand-alone ITS/TSM&O project. Otherwise, prefer Design-Bid-Build.
- D: Provides the owner the ability to clearly define requirements and expectations.
- E: System Manager because it provides flexibility, lower costs and the latest technology.
- F: Bill of Materials.
- G: It needs to fit the job. Usually we know enough to use Design Bid Build.

Table C.4: Procurement Practices

District	Title of Participant	Procurement Practices: These are the procedures agencies use to evaluate and select designers, contractors, and various consultants. Please list example project types for all the procurement practices currently being used by your agency.								
		Cost-Plus-Time Bidding (A+B)	Multi-Parameter Bidding (A+B+C)	Lump Sum Bidding	Alternate Design	Alternate Bid	Additive Alternates	Best-Value Procurement	Bid Averaging	Other
1	FMS/AMS Specialist IV			A		FMS, ATMS		B		
2	TSM&O Program Manager	N/A	N/A	I-95	N/A	N/A	N/A	N/A	X	System Manager
3	TSMO Project Engineer	No Answer								
4	District TSM&O Engineer									C
	Freeway Operations Manager	No Answer								
	District 4 LCIS Administrator	No Answer								
	ITS Ops Manager	Most								
5	TSMO Engineer Freeways	I-75 ITS		RTMC			DASH IV	ICM		Low Bid: TSP
6	TSM&O Program Engineer	No Answer								
7	ITS Program Manager	No Answer								
Turnpike	Traffic Services Engineer	No Answer								

A: FMS, ATMS, ASCT, IMS

B: ASCT equipment bid

C: Adjusted score - factors price, schedule, and technical score

Table C.5: Preferred TSM&O and ITS Project Procurement Method

District	Title of Participant	Which procurement method do you think is best for TSM&O (and ITS) projects? Why?									
		Cost-Plus-Time Bidding (A+B)	Multi-Parameter Bidding (A+B+C)	Lump Sum Bidding	Alternate Design	Alternate Bid	Additive Alternates	Best-Value Procurement	Bid Averaging	Other	Not sure
1	FMS/AMS Specialist IV			C							
2	TSM&O Program Manager									E	
3	TSMO Project Engineer							D			
4	District TSM&O Engineer										X
	Freeway Operations Manager	No Answer									
	District 4 LCIS Administrator	No Answer									
	ITS Ops Manager	A									
5	TSMO Engineer Freeways									F	
6	TSM&O Program Engineer		B								
7	ITS Program Manager	No Answer									
Turnpike	Traffic Services Engineer										X

A: If the processes are followed by the other PMs it can work well.

B: Quality needs to be part of the equation whenever you are dealing with systems.

Table C.5: Preferred TSM&O and ITS Project Procurement Method (continued)

- C: They are predictable and easier to manage because of their relative simplicity. Limits FDOT's financial exposure during construction. Provides a relative amount of cost certainty. Contractor typically provides better management of contract to stay within budget. Need good oversight to ensure compliance with requirements, otherwise contractor could cut corners to increase profit.
- D: Value is important.
- E: System Manager to keep up with the latest technology.
- F: Low Bid most of the time; again it needs to fit the project.

Table C.6: Contract Management Methods

District	Title of Participant	Contract Management Methods: These refer to the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. Please list example project types for all the contract management methods currently being used by your agency.						
		Incentives/Disincentives (I/D) Provisions for Early Completion	Lane Rental	Flexible Notice to Proceed Dates	Liquidated Savings	Active Management Payment Mechanism (AMPM)	No Excuse Incentives	Other
1	FMS/AMS Specialist IV							B
2	TSM&O Program Manager	N/A	N/A	N/A	N/A	N/A	No-Excuse Incentives	System manager
3	TSMO Project Engineer	No Answer						
4	District TSM&O Engineer	No Answer						
	Freeway Operations Manager	No Answer						
	District 4 LCIS Administrator	No Answer						
	ITS Ops Manager	Managed Lane Projects						
5	TSMO Engineer Freeways							C
6	TSM&O Program Engineer	A						
7	ITS Program Manager	No Answer						
Turnpike	Traffic Services Engineer	No Answer						

A: This typically leads to "cutting corners" (water down testing, accepting subpar projects, etc.).

B: CPAM-liquidated damages, DWL/DL, CPPR

C: Road has dictated the use of above. I could list projects but I don't think it will serve the objective.

Table C.7: Preferred TSM&O and ITS Project Contract Management Method

District	Title of Participant	Which contract management method do you think is best for TSM&O (and ITS) projects? Why?							
		Incentives/Disincentives (I/D) Provisions for Early Completion	Lane Rental	Flexible Notice to Proceed Dates	Liquidated Savings	Active Management Payment Mechanism (AMPM)	No Excuse Incentives	Other	Not sure
1	FMS/AMS Specialist IV								X
2	TSM&O Program Manager							A	
3	TSMO Project Engineer								X
4	District TSM&O Engineer								X
	Freeway Operations Manager								X
	District 4 LCIS Administrator								X
	ITS Ops Manager							B	
5	TSMO Engineer Freeways							C	
6	TSM&O Program Engineer								X
7	ITS Program Manager	<i>No Answer</i>							
Turnpike	Traffic Services Engineer								X

A: System Manager - sets delivery date and ensures the final product meets the intent of the project.

B: None. Another process where the end user manages the process should be used.

C: None of the above. Our dollar amounts don't warranty it. It would have to be a safety issue that needs to be addressed immediately to use one of these.

Table C.8: Funding Sources for TSM&O Activities

District	Title of Participant	What funding sources are used for TSM&O activities by your District? Select all that apply.									
		Congestion Mitigation and Air Quality Improvement (CMAQ) Program	Surface Transportation Program (STP)	Highway Safety Improvement Program (HSIP)	National Highway Performance Program (NHPP)	Transportation Investment Generating Economic Recovery (TIGER)	Highway User Revenue Fund	Local Taxes	Unified Planning Work Program (UPWP)	Public-Private Partnership	Other
1	FMS/AMS Specialist IV			X			X				
2	TSM&O Program Manager	X	X	X				X			State Funds
3	TSMO Project Engineer	No Answer									
4	District TSM&O Engineer										A
	Freeway Operations Manager	No Answer									
	District 4 LCIS Administrator	No Answer									
	ITS Ops Manager	No Answer									
5	TSMO Engineer Freeways		X	X				X	X	X	District Funds
6	TSM&O Program Engineer									X	
7	ITS Program Manager	No Answer									
Turnpike	Traffic Services Engineer										Toll Revenue

A: Not sure, we need a better understanding of funds can be used for TSM&O and how (capital vs. O&M) in general.

Table C.9: Funding Strategies for TSM&O Projects

District	Title of Participant	Please identify the strategies used by your District to fund TSM&O projects.				Which system development strategy (i.e., model) does your District adopt for TSM&O and ITS projects. Select all that apply.				
		We set aside dedicated funding for TSM&O projects	We allow TSM&O projects to compete with other types of projects for funding	We combine a set-aside with the ability for TSM&O projects to compete for other funding	Other	Waterfall Model	Agile Model	Incremental Build Model	Spiral Model	Other
1	FMS/AMS Specialist IV			X		X				
2	TSM&O Program Manager			X			X			
3	TSMO Project Engineer				N/A					N/A
4	District TSM&O Engineer		X			X				
	Freeway Operations Manager	No Answer				No Answer				
	District 4 LCIS Administrator		X			No Answer				
	ITS Ops Manager				A	X				
5	TSMO Engineer Freeways		X			X	X	X		
6	TSM&O Program Engineer	X				X				
7	ITS Program Manager	No Answer				No Answer				
Turnpike	Traffic Services Engineer	X				No Answer				

A: Ad-hoc for construction.

Table C.10: System Development Model Challenges for TSM&O and ITS Projects

District	Title of Participant	What challenges, if any, are you currently encountering with the system development model that you have adopted for TSM&O and ITS projects?
1	FMS/AMS Specialist IV	None that we are aware.
2	TSM&O Program Manager	Old school thinking by professionals who are frightened by the evolution of technology.
3	TSMO Project Engineer	Lack of resources and designated funding.
4	District TSM&O Engineer	Lack of upper management and staff level understanding for how systems work individually and with other systems. An express lanes project will only work if the ITS and Tolling system works, but the system is not the biggest expense so it doesn't get the same attention as the bigger ticket items. How systems are to be planned for, designed, how they operate and how they should be maintained is not understood outside of TSM&O experts.
	Freeway Operations Manager	<i>No Answer</i>
	District 4 LCIS Administrator	<i>No Answer</i>
	ITS Ops Manager	<i>No Answer</i>
5	TSMO Engineer Freeways	Prequalification.
6	TSM&O Program Engineer	Resistance from other FDOT offices due to lack of understanding of systems engineering.
7	ITS Program Manager	<i>No Answer</i>
Turnpike	Traffic Services Engineer	<i>No Answer</i>

APPENDIX D: District Survey II Questionnaire

District Survey II Questionnaire

Dear Participant:

Thank you for accepting our invitation to complete this survey!

The Florida Department of Transportation is conducting this survey to learn about how Transportation Systems Management and Operations (TSM&O) strategies, relating to roadway projects, are addressed in your district. TSM&O is defined by the Federal Highway Administration as the use of “integrated strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve the security, safety, and reliability of the transportation system.” Management and Operations (M&O) efforts vary across transportation modes, and include:

- Traffic Incident Management
- Traffic detection and surveillance
- Corridor, freeway, and arterial management
- Active transportation and demand management
- Work zone management
- Road weather management
- Emergency management
- Traveler information services
- Congestion pricing
- Parking management
- Automated enforcement Traffic control
- Commercial vehicle operations
- Freight management
- Coordination of highway, rail, transit, bicycle, and pedestrian operations

We estimate that it will take you less than 10 minutes to complete this survey. If you have any questions or comments about this survey, please contact:

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1. Please list your FDOT District number (use 8 for Turnpike Enterprise).

2. Please provide your information below:

Name:

Title:

Address:

Phone:

Email:

3. When is TSM&O (includes ITS) considered in the project development process in your District? *Select all that apply.*

- Planning
- Design
- Construction
- Operations
- None
- Not sure

4. What project development phase are you most often involved in? *Select one.*

- Procurement
- Planning
- PD&E
- Design
- Construction

Other, please explain:

5. How often do you consider TSM&O during the project development phase that you selected in the previous question?

- Never
- Rarely
- Sometimes
- Always

6. Do you engage TSM&O officials in your District? If yes, please explain the process.

- Yes
- No
- Not sure
- If yes, process:



7. Is there a project that you were involved in where a TSM&O strategy was used? If yes, please describe the project and your experiences relating to TSM&O activities.

- Yes
- No
- Not sure
- If yes, please describe:



8. How would you rate your level of understanding of TSM&O overall?

- A great deal
- A lot
- A moderate amount
- A little
- None at all

9. How important do you consider TSM&O is in the project development process?

- Very important
- Somewhat important
- A little important
- Not very important

10. Have you received training on TSM&O, i.e., presentation, workshop, flyer? If yes, please describe the type and year of the training.

- Yes
- No

- Type of training:
- Year of training:

11. Have you used the Systems Engineering (SE) process for ITS components on projects? If yes, describe what parts of the SE process you have had experience with using.

- Yes
- No
- Not sure
- If yes, please describe:

12. How often do you develop Systems Engineering documents?

- All projects
- Some projects
- Not sure
- Do not use the Systems Engineering process

13. Please describe how you develop TSM&O project concepts.

14. Please describe any roadblocks or issues you have experienced when including TSM&O concepts in the projects you usually work with.

15. What are your thoughts on how projects should be planned for while considering TSM&O?

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16. What areas of training, related to TSM&O, do you feel you need more of?

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The following questions pertain to construction project managers:

17. Please describe your experiences during the field installation of ITS components, i.e., issues, difficulties, successes, or no experience.

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18. Please describe your experiences during unit/device testing of ITS components, i.e., issues, difficulties, successes, or no experience.

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19. Please describe your experiences during subsystem or system verification and deployment, i.e., issues, difficulties, successes, or no experience. Were project requirements and ConOps met?

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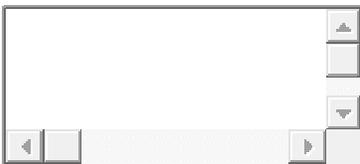
20. Please describe your experiences during system validation, i.e., issues, difficulties, successes, or no experience. Were project requirements and ConOps met?

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21. How should TSM&O staff assist during the validation process?

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22. Does Construction need more tools to determine if TSM&O/ITS requirements are met?

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Thank you.

APPENDIX E: District Survey II – Responses

Table E.1: TSM&O in the Project Development Process

District	Participant Position Title	When is TSM&O (includes ITS) considered in the project development process in your District?					
		Planning	Design	Construction	Operations	None	Not sure
1	Intermodal Systems Development (ISD) Administrator	X	X		X		
2	FLPO Manager	X	X	X			
	Urban Planning Manager	X	X				
4	Consultant Project Manager	X	X		X		
	Consultant Project Manager	X	X	X			
	District Consultant Management Engineer	X	X	X	X		
	District Planning & Environmental Engineer	X	X	X	X		
	Concept Development Supervisor	X					
	Transportation Planning Manager	X			X		
5	Transportation Planning Manager	X	X	X	X		
	District Consultant Project Management Engineer (DCPME)	X	X				
	Modal Development Administrator	X	X	X	X		
	Asst. District Construction Manager		X				

Table E.2: Project Development Phase Involvement

District	Participant Position Title	What project development phase are you most often involved in?					
		Procurement	Planning	PD&E	Design	Construction	Other
1	Intermodal Systems Development (ISD) Administrator		X				
2	FLPO Manager		X				
	Urban Planning Manager		X				
4	Consultant Project Manager				X		
	Consultant Project Manager				X		
	District Consultant Management Engineer				X		
	District Planning & Environmental Engineer		X				
	Concept Development Supervisor		X				
	Transportation Planning Manager		X				
5	Transportation Planning Manager		X				
	District Consultant Project Management Engineer (DCPME)				X		
	Modal Development Administrator						Multi-Modal Development
	Asst. District Construction Manager					X	

Table E.3: TSM&O Consideration and Interaction with Staff

District	Participant Position Title	How often do you consider TSM&O during the project development phase that you selected in the previous question?				Do you engage TSM&O officials in your District? If yes, please explain the process.		
		Never	Rarely	Sometimes	Always	Yes	No	Process
1	Intermodal Systems Development (ISD) Administrator	<i>No Answer</i>				X		A
2	FLPO Manager	<i>No Answer</i>						B
	Urban Planning Manager	<i>No Answer</i>						C
4	Consultant Project Manager			X		X		D
	Consultant Project Manager			X		X		E
	District Consultant Management Engineer			X		X		F
	District Planning & Environmental Engineer			X		X		G
	Concept Development Supervisor		X			X		H
	Transportation Planning Manager			X		X		I
5	Transportation Planning Manager	<i>No Answer</i>				X		--
	District Consultant Project Management Engineer (DCPME)			X		X		J
	Modal Development Administrator	<i>No Answer</i>				<i>No Answer</i>		
	Asst. District Construction Manager	<i>No Answer</i>				X		K

A: Meeting discussion, high level of coordination between work groups.

Table E.3: TSM&O Consideration and Interaction with Staff (continued)

- B: We discuss options with our ITS department and we are involved with TSM&O as it relates to Bus Rapid Transit Projects with the Jacksonville Transportation Authority.
- C: Our ITS coordinator is involved in the scope process at the beginning of project. Traffic Operations is also involved by providing a list of potential TSM&O projects in candidate or unfunded needs lists. Planning Studies are routed through traffic operations during the development. MPOs often do, and are encouraged to, include TSM&O strategies in their goals and objectives and projects for Long Range Plans.
- D: No known process. Direct contact if part of project scope or if a TSM&O option is considered.
- E: Discuss upcoming ITS and intersection projects to coordinate any future TSM&O opportunities.
- F: During development of the MOT plan for a project and evaluation of alternatives.
- G: Coordinate scope development with other offices, including the Traffic Operations (ITS) group.
- H: Engaging has been as a reactive mode when typical capacity options have been exhausted.
- I: With new planning studies we engage our Traffic Operations TSM&O Section to provide input and guidance, and hire consultants to provide concepts that involve TSM&O.
- J: Jeremy Dilmore (*District 5 ITS Manager*) is our point of contact and we coordinate with him.
- K: When there is an issue, we contact the DTop [*District Traffic Operations*] engineer.

Table E.4: TSM&O Project Involvement and Level of Understanding

District	Participant Position Title	Is there a project that you were involved in where a TSM&O strategy was used? If yes, please describe the project and your experiences relating to TSM&O activities.				How would you rate your level of understanding of TSM&O overall?				
		Yes	No	Not sure	Description	A great deal	A lot	A moderate amount	A little	None at all
1	Intermodal Systems Development (ISD) Administrator	X			A				X	
2	FLPO Manager	X			B			X		
	Urban Planning Manager	<i>No Answer</i>						X		
4	Consultant Project Manager		X					X		
	Consultant Project Manager	X			C				X	
	District Consultant Management Engineer	X			D			X		
	District Planning & Environmental Engineer	X			E			X		
	Concept Development Supervisor	X			F				X	
	Transportation Planning Manager	X			G				X	
5	Transportation Planning Manager	X			H	X				
	District Consultant Project Management Engineer (DCPME)	X			I				X	
	Modal Development Administrator	<i>No Answer</i>						X		
	Asst. District Construction Manager			X	J			X		

Table E.4: TSM&O Project Involvement and Level of Understanding (continued)

A: Adaptive signal system.

B: In the development of Interstate Master Plans we always include short term TSM&O recommendations.

C: We have a project on Indiantown Road where we are coordinating with the county for ATMS to incorporate TSM&O within the scope.

D: Currently working on a bridge replacement project and evaluating phased construction v. a detour. TSM&O improvements would be needed along the detour to address additional traffic.

E: I-95 Express Lanes.

F: Queue detection, adaptive signals.

G: 95 Express Lanes, 75 Express Lanes projects.

H: We are always looking to improve the operational efficiency of the transportation network.

I: Please refer to Jeremy Dilmore (*District 5 ITS Manager*) for details.

J: Not sure what is meant by TSM&O strategy.

Table E.5: TSM&O Importance and Training

District	Participant Position Title	How important do you consider TSM&O is in the project development process?				Have you received training on TSM&O, i.e., presentation, workshop, flyer? If yes, please describe the type and year of the training.			
		Very important	Somewhat important	A little important	Not very important	Yes	No	Type	Year
1	Intermodal Systems Development (ISD) Administrator	X				X		A	--
2	FLPO Manager	X				X		B	--
	Urban Planning Manager	X				X		C	2012, 2014
4	Consultant Project Manager	X					X		
	Consultant Project Manager			X			X		
	District Consultant Management Engineer		X				X		
	District Planning & Environmental Engineer	X					X		
	Concept Development Supervisor		X				X		
	Transportation Planning Manager		X				X		
5	Transportation Planning Manager	X				X		D	2016
	District Consultant Project Management Engineer (DCPME)	X					X		
	Modal Development Administrator	X				X		E	--
	Asst. District Construction Manager	X					X		

Table E.5: TSM&O Importance and Training (continued)

A: Discussion with subject matter experts in district, presentations, flyers, workshops, etc.

B: Workshops, presentations and reading research papers.

C: Statewide workshop on Opportunities for Integrating TSM&O Dec. 12, 2012, Tallahassee; FDOT District 2 TSMO Workshop, Jacksonville Urban Office, May 23, 2012, and again in District 2 Urban Office April 10, 2014.

D: I attend Bi-monthly TSMO Consortium Meetings, and weekly TSMO meetings with Traffic Operations Staff and Consultants.

E: Presentation.

Table E.6: Systems Engineering Process and Document Development

District	Participant Position Title	Have you used the Systems Engineering (SE) process for ITS components on projects? If yes, describe what parts of the SE process you have had experience with using.				How often do you develop Systems Engineering (SE) documents?			
		Yes	No	Not sure	Description	All projects	Some projects	Not sure	Do not use SE process
1	Intermodal Systems Development (ISD) Administrator		X		No experience using.				X
2	FLPO Manager		X						X
	Urban Planning Manager		X						X
4	Consultant Project Manager			X				X	
	Consultant Project Manager		X					X	
	District Consultant Management Engineer		X						X
	District Planning & Environmental Engineer		X					X	
	Concept Development Supervisor		X						X
	Transportation Planning Manager		X						X
5	Transportation Planning Manager		X						X
	District Consultant Project Management Engineer (DCPME)			X				X	
	Modal Development Administrator		X						X
	Asst. District Construction Manager		X						X

Table E.7: TSM&O Project Concepts

District	Participant Position Title	Please describe how you develop TSM&O project concepts.	Please describe any roadblocks or issues you have experienced when including TSM&O concepts in the projects you usually work with.
1	Intermodal Systems Development (ISD) Administrator	Consider in planning documents and promote planning of TSM&O with MPOs.	<i>No Answer</i>
2	FLPO Manager	During the Master Plan project we look at intersections or other areas that could be improved using TSM&O project concepts.	Funding is always an issue.
	Urban Planning Manager	Usually at planning level it is in planning/corridor studies as alternatives or recommendations for corridor.	<i>No Answer</i>
4	Consultant Project Manager	I have not developed a concept.	No known process to vet TSM&O Options. Lack of knowledge on when options are applicable. Lack of Training.
	Consultant Project Manager	This gets coordinated with our design and traffic operations offices.	Money is not always available for project integration.
	District Consultant Management Engineer	I rely on our TSM&O experts in the District.	None.
	District Planning & Environmental Engineer	Assess the network needs and prioritize projects to maximize the available capacity. D4 is currently working on a TSM&O Master Plan to develop the core TSM&O network, assess needs, and prioritize projects.	Funding for operations and maintenance.
	Concept Development Supervisor	<i>No Answer</i>	Major issues is the understanding of how the TSM&O strategies work, the design aspects that need to be considered during planning phases, analysis if any required and cost for LRE purposes. District TSM&O staff may or may not have the answer to the issues described above.
	Transportation Planning Manager	In planning, we consider how technology can help to optimize the signals and usage of lanes, to reduce recurring congestion hotspots. Also, we are considering what corridors to implement TSM&O strategies such as DMS signs and other strategies. Our District is working on developing a TSM&O Master Plan for 2 of our 5 counties.	Challenges with identifying an ongoing and increasing annual funding pot for operations of new ITS devices.

Table E.7: TSM&O Project Concepts (continued)

District	Participant Position Title	Please describe how you develop TSM&O project concepts.	Please describe any roadblocks or issues you have experienced when including TSM&O concepts in the projects you usually work with.
5	Transportation Planning Manager	I work with Operations, planning and design to implement TSMO improvements.	Funding
	District Consultant Project Management Engineer (DCPME)	Jeremy Dilmore* is our point of contact for this information as he is our expert.	If it is not addressed early on, it can change the design and cost us money and time.
	Modal Development Administrator	<i>No Answer</i>	<i>No Answer</i>
	Asst. District Construction Manager	They are developed during design. We incorporate them into the construction of the project.	Usually handled in design.

* District 5 ITS Manager

Table E.8: Project Planning and Additional Training

District	Participant Position Title	What are your thoughts on how projects should be planned for while considering TSM&O?	What areas of training, related to TSM&O, do you feel you need more of?
1	Intermodal Systems Development (ISD) Administrator	Need better understanding of how to consider and include at planning level.	All areas and ensure appropriate staff are trained.
2	FLPO Manager	Include TSM&O as early as possible, add to the scope of services for a project.	All areas.
	Urban Planning Manager	<i>No Answer</i>	<i>No Answer</i>
4	Consultant Project Manager	TSM&O should be considered for all projects during all phases. Overall we need smarter transportation infrastructure.	All
	Consultant Project Manager	It should just be another checkbox of coordination that has been funded from a master plan so that we can incorporate into our plans.	What it is and how it works overview. I also think we need more designers looking at how to integrate them into our designs.
	District Consultant Management Engineer	<i>No Answer</i>	General TSM&O concepts and practices. Enough to determine when TSM&O is a viable option for projects and to have an informed discussion with the TSM&O experts in the District.
	District Planning & Environmental Engineer	Should be a component of, or a consideration in most projects; especially major investment projects.	Technical training on the benefits and best practices of TSM&O.
	Concept Development Supervisor	TSM&O should be part of any project but it is understood that TS&M alone it won't solve oversaturated flow conditions.	Type of TSM&O strategies, pro and cons overview, TSM&O strategies traffic analysis, and cost estimation.
	Transportation Planning Manager	TSM&O concepts/strategies should be applied along with traditional strategies. Our District also will have a Master Plan to refer back to, and guide us in which corridors should have a concentration on TSM&O for various proposes such as for freight, or transit, or general all traffic needs.	All areas, planning, design, construction, operations, and maintenance. As well as cost information, and an overview of the types of expertise needed (computer engineering and electrical engineering) to help identify appropriate strategies, and how to design and construct components/devices to the central traffic management center system.

Table E.8: Project Planning and Additional Training (continued)

District	Participant Position Title	What are your thoughts on how projects should be planned for while considering TSM&O?	What areas of training, related to TSM&O, do you feel you need more of?
5	Transportation Planning Manager	Incorporate TSMO during the PD&E and Design Scoping efforts.	None.
	District Consultant Project Management Engineer (DCPME)	In the early phases.	Not sure.
	Modal Development Administrator	<i>No Answer</i>	<i>No Answer</i>
	Asst. District Construction Manager	<i>No Answer</i>	<i>No Answer</i>

Table E.9: ITS Component Installation and Testing Experiences

District	Participant Position Title	Please describe your experiences during the field installation of ITS components, i.e., issues, difficulties, successes, or no experience.	Please describe your experiences during unit/device testing of ITS components, i.e., issues, difficulties, successes, or no experience.
1	Intermodal Systems Development (ISD) Administrator	No experience.	No experience.
2	FLPO Manager	<i>No Answer</i>	<i>No Answer</i>
	Urban Planning Manager	<i>No Answer</i>	<i>No Answer</i>
4	Consultant Project Manager	None.	None.
	Consultant Project Manager	My issues with ITS is not know[ing] all the specifics of what is needed to integrate the pay items into our plans.	None.
	District Consultant Management Engineer	<i>No Answer</i>	<i>No Answer</i>
	District Planning & Environmental Engineer	None.	None.
	Concept Development Supervisor	No experience.	No experience.
	Transportation Planning Manager	No field experience.	No experience.
5	Transportation Planning Manager	<i>No Answer</i>	<i>No Answer</i>
	District Consultant Project Management Engineer (DCPME)	It's been successful.	Jeremy Dilmore* will be the point of contact for details.
	Modal Development Administrator	<i>No Answer</i>	<i>No Answer</i>
	Asst. District Construction Manager	Power is not always readily available or contemplated by the designers. Technology changes so quickly, that designated components are frequently outdated and/or unavailable.	Our Traffic Operations folks are always willing to work with us to test the constructed system.

* District 5 ITS Manager

Table E.10: System Deployment and Validation Experiences

District	Participant Position Title	Please describe your experiences during subsystem or system verification and deployment, i.e., issues, difficulties, successes, or no experience. Were project requirements and ConOps met?	Please describe your experiences during system validation, i.e., issues, difficulties, successes, or no experience. Were project requirements and ConOps met?
1	Intermodal Systems Development (ISD) Administrator	No experience.	No experience.
2	FLPO Manager	<i>No Answer</i>	<i>No Answer</i>
	Urban Planning Manager	<i>No Answer</i>	<i>No Answer</i>
4	Consultant Project Manager	None.	None.
	Consultant Project Manager	None.	None.
	District Consultant Management Engineer	<i>No Answer</i>	<i>No Answer</i>
	District Planning & Environmental Engineer	None.	None.
	Concept Development Supervisor	No experience.	No experience.
	Transportation Planning Manager	No experience.	No experience.
5	Transportation Planning Manager	<i>No Answer</i>	<i>No Answer</i>
	District Consultant Project Management Engineer (DCPME)	See Jeremy Dilmore*.	See Jeremy Dilmore.
	Modal Development Administrator	<i>No Answer</i>	<i>No Answer</i>
	Asst. District Construction Manager	<i>No Answer</i>	<i>No Answer</i>

* District 5 ITS Manager

Table E.11: Additional Assistance for Construction Project Managers

District	Participant Position Title	How should TSM&O staff assist during the validation process?	Does Construction need more tools to determine if TSM&O/ITS requirements are met?
1	Intermodal Systems Development (ISD) Administrator	Not sure.	Not sure.
2	FLPO Manager	<i>No Answer</i>	<i>No Answer</i>
	Urban Planning Manager	<i>No Answer</i>	<i>No Answer</i>
4	Consultant Project Manager	Unknown, but since they are the only in-house staff knowledgeable in the subject area I would assume they should be involved.	Unknown.
	Consultant Project Manager	Not sure.	Sure.
	District Consultant Management Engineer	<i>No Answer</i>	<i>No Answer</i>
	District Planning & Environmental Engineer	Not sure.	Probably.
	Concept Development Supervisor	Not Applicable	Not Applicable
	Transportation Planning Manager	I don't understand what this is asking.	Unknown.
5	Transportation Planning Manager	<i>No Answer</i>	<i>No Answer</i>
	District Consultant Project Management Engineer (DCPME)	This should be a part of the process.	Unsure.
	Modal Development Administrator	<i>No Answer</i>	<i>No Answer</i>
	Asst. District Construction Manager	They are the experts. They should be involved.	<i>No Answer</i>

APPENDIX F: State DOT Questionnaire

State DOT Questionnaire

1. Please provide your information below:

Name:

Title:

Agency:

Address:

Phone:

Email:

2. Is there a TSM&O and/or ITS division in your agency? *Select all that apply.*

- TSM&O Division
- ITS Division
- Neither

3. If your agency currently has a TSM&O division, when was it established?

Year

4. If your agency currently has a TSM&O division, what is the designation and title of the top TSM&O official within your agency?

5. What is the position of the top TSM&O official within your agency?

- Director Level
- Technical Level
- Other, please specify:

6. When developing roadway projects, i.e., widening, resurfacing, interstate safety improvements, etc., do TSM&O or ITS officials get involved?

- Yes
- No
- Sometimes
- Not sure
- Other, please elaborate:

7. Consider the following typical project development process. When do TSM&O officials get involved? *Select all that apply.*

- Planning
- Design
- Construction
- Operations
- None
- Not sure

8. Do TSM&O officials review potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase?

- Yes
- No
- Not sure
- Other, please elaborate:

9. How much is TSM&O covered in design process guidelines, such as in planning guidelines, design manuals, etc.?

- A great deal
- A lot
- A moderate amount
- A little
- None at all

10. Does your agency have guidelines stating how TSM&O should be incorporated in the project development process prior to Operations?

- Yes
- No
- Not sure
- Other, please elaborate:

11. Does your agency have any literature or case studies showing how TSM&O was incorporated in current or previous projects, outside of M&O projects?

- Yes
- No
- I don't know
- Other, please elaborate:

12. What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?

13. Does your agency utilize the Capability Maturity Model (CMM) framework to help improve the effectiveness of TSM&O activities?

- Yes
- No
- Not sure
- Other, please elaborate:

For each of the Capability Maturity Model (CMM) Dimension, please select the appropriate capability level your agency is currently operating within the TSM&O program.

14. CMM Dimension: Business Processes (Planning, Programming, Budgeting, Implementation)

- Level 1: Processes related to TSM&O ad hoc and unintegrated
- Level 2: Multiyear statewide TSM&O plan and program exists with deficiencies, evaluation, and strategies
- Level 3: Programming, budgeting, and project development processes for TSM&O standardized and documented
- Level 4: Processes streamlined and subject to continuous improvement
- Not sure

15. CMM Dimension: Systems & Technology (Systems Engineering, Standards, and Technology Interoperability)

- Level 1: Ad hoc approaches outside systematic systems engineering
- Level 2: Systems Engineering employed and consistently used for concept of operations, architecture, and systems development
- Level 3: Systems and technology standardized, documented, and trained statewide, and new technology incorporated
- Level 4: Systems and technology routinely upgraded and utilized to improve efficiency performance
- Not sure

16. CMM Dimension: Performance Measurement (Measures, Data & Analytics, and Utilization)

- Level 1: No regular performance measurement related to TSM&O
- Level 2: TSM&O strategies measurement largely via outputs, with limited after-action analysis
- Level 3: Outcome measures identified and consistently used for TSM&O strategies improvement
- Level 4: Mission-related outputs/outcomes data routinely utilized for management, reported internally and externally, and archived
- Not sure

17. CMM Dimension: Culture (Technical Understanding, Leadership, Outreach, and Program Authority)

- Level 1: Value of TSM&O not widely understood beyond champions
- Level 2: Agency-wide appreciation of the value and role of TSM&O
- Level 3: TSM&O accepted as a formal core program
- Level 4: Explicit agency commitment to TSM&O as key strategy to achieve full range of mobility, safety, and livability/sustainability objectives
- Not sure

18. CMM Dimension: Organization/Workforce (Organizational Structure and Workforce Capability Development)

- Level 1: Fragmented roles based on legacy organization and available skills
- Level 2: Relationship among roles and units rationalized and core staff capabilities identified
- Level 3: Top-level management position and core staff for TSM&O established in central office and districts
- Level 4: Professionalization and certification of operations core capacity positions including performance incentives
- Not sure

19. CMM Dimension: Collaboration (Partnerships among Levels of Government and with Public Safety Agencies and Private Sector)

- Level 1: Relationships on informal, infrequent, and on personal basis
- Level 2: Regular collaboration at regional level
- Level 3: Collaborative interagency adjustment of roles/ responsibilities by formal interagency agreements
- Level 4: High level of operations coordination institutionalized among key players – public and private
- Not sure

The following questions focus on the project delivery systems, procurement practices, contract management methods, and funding sources pertaining to TSM&O and ITS projects.

20. Project Delivery Systems: These refer to the overall processes by which a project is designed, constructed, and/or maintained). *Please list example project types for all the project delivery systems currently being used by your agency. Please hover over the options for more information.*

Design-Build:

Design-Bid-Build:

Design Sequencing:

Indefinite Delivery/Indefinite Quantity (ID/IQ):

Agency-Construction Manager:

Construction Manager at-Risk:

Contract Maintenance:

Other (please elaborate):

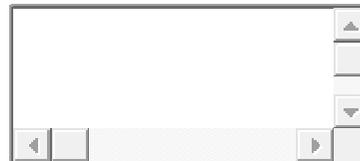
The image shows a vertical stack of eight empty text input fields. Each field is rectangular with a light gray background and a thin border. On the right side of each field, there are three small, light gray buttons: a triangle pointing up, a square, and a triangle pointing down. Below each field, there is a horizontal scrollbar with a light gray track and a white slider. The fields are currently empty, intended for the user to list example project types for each delivery system.

21. If your agency uses Design-Build project delivery system, does it include any of the following: *Select all that apply.*

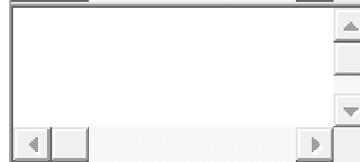
- Design-Build-Warranty
- Design-Build-Maintain
- Design-Build-Operate
- Design-Build-Operate-Maintain
- We don't use Design-Build system
- Not sure

22. Procurement Practices: These are the procedures agencies use to evaluate and select designers, contractors, and various consultants. Please list example project types for all the procurement practices currently being used by your agency. Please hover over the options for more information.

Cost-Plus-Time Bidding (A+B):



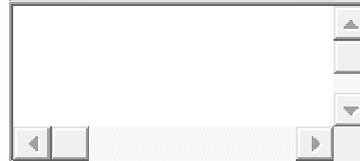
Multi-Parameter Bidding (A+B+C):



Lump Sum Bidding:



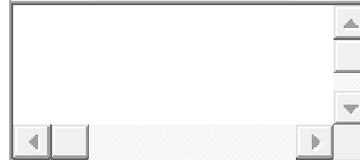
Alternate Design:



Alternate Bid:



Additive Alternates:



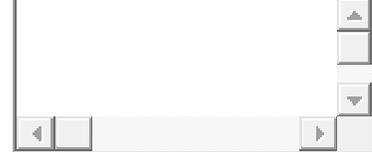
Best-Value Procurement:



Bid Averaging:



Other (please elaborate):



23. Contract Management Methods: These refer to the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. *Please list example project types for all the contract management methods currently being used by your agency. Please hover over the options for more information.*

Incentives/Disincentives (I/D) Provisions for Early Completion:



Lane Rental:



Flexible Notice to Proceed Dates:



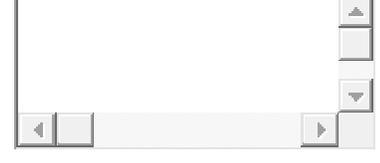
Liquidated Savings:



Active Management Payment Mechanism (AMPM):



No Excuse Incentives:



Other (please elaborate):

24. What funding sources are used for TSM&O activities by your agency? *Select all that apply.*

- Congestion Mitigation and Air Quality Improvement (CMAQ) Program
- Surface Transportation Program (STP)
- Highway Safety Improvement Program (HSIP)
- National Highway Performance Program (NHPP)
- Transportation Investment Generating Economic Recovery (TIGER)
- Highway User Revenue Fund
- Local Taxes
- Unified Planning Work Program (UPWP)
- Public-Private Partnership
- Other, please specify:

25. Please identify the strategies used by your agency to fund TSM&O projects.

- We set aside dedicated funding for TSM&O projects
- We allow TSM&O projects to compete with other types of projects for funding
- We combine a set-aside with the ability for TSM&O projects to compete for other funding
- Other, please specify:

26. Which system development strategy (i.e., model) does your agency adopt for TSM&O and ITS projects. *Select all that apply. Please hover over the options for more information.*

- Waterfall Model
- Agile Model
- Incremental Build Model
- Spiral Model
- Other, please specify:

APPENDIX G: State DOT Survey – Part I Responses

Table G.1: TSM&O Divisions

State	Is there a TSM&O and/or ITS division in your agency?			If your agency currently has a TSM&O program, when was it established?	If your agency currently has a TSM&O division, what is the designation and title of the top TSM&O official within your agency?		What is the position of the top TSM&O official within your agency?		
	TSM&O	ITS	Neither		Year	Designation	Title	Director	Technical
Alabama	X			2016	TSM&O	Asst. State Maintenance Engineer			Asst. State Maintenance Engineer
Alaska			X						
Arizona	X			2015	TSM&O Division	Division Director	X		
Arkansas			X						
Colorado	X	X		2014	Division of TSM&O	Director	X		
Connecticut			X						
Delaware			X					X	
Florida	X			1995		TSM&O Program Engineer		X	
Georgia		X					X		
Hawaii			X					X	
Illinois		X						X	
Iowa	X	X		2012	Systems Operations Bureau	Director	X		
Kansas			X	2015					
Kentucky			X						
Maine			X					X	
Maryland	X				Office of CHART & ITS	Director	X		
Michigan			X						
Minnesota	X	X		2016	Operations Division	TSM&O Manager	X		
Missouri			X			Traffic and Highway Safety Engineer			Traffic and Highway Safety Engineer
Nevada		X			Traffic Operations	<i>No Answer</i>			
New Hampshire	X	X		2014	<i>No Answer</i>	Administrator			Administrator
New Jersey	X	X		2011	Transportation Systems Management (TSM)	Assistant Commissioner	X		
North Carolina			X				X		
North Dakota		X							
Ohio			X						
Oklahoma			X						
Oregon			X					X	
Pennsylvania			X		Planning and Operations	Section Chief			Section Chief
South Dakota			X					X	
Tennessee	X			2013	Traffic Operations Division	Director	X		
Texas		X						X	
Utah	X			1999	Traffic Operations	Engineer		X	
Vermont	X			2015	<i>No Answer</i>	TSMO Manager	X		
Virginia	X			2006	<i>No Answer</i>	State Operations Engineer	X		
Washington	X			1995	Traffic Operations	Director	X		
West Virginia			X						

Table G.2: Project Development Process

State	When developing roadway projects, i.e., widening, resurfacing, interstate safety improvements, etc., do TSM&O or ITS officials get involved?					Considering the following typical project development process. When do TSM&O officials get involved?						Do TSM&O officials review potential projects to determine if TSM&O strategies offer a viable solution over traditional capacity-driven solutions before a project enters the design phase?			
	Yes	No	Sometimes	Not sure	Other	Planning	Design	Construction	Operations	None	Note sure	Yes	No	Not sure	Other
Alabama			X			X	X		X					X	
Alaska	X										X			X	
Arizona					A	X	X	X	X						E
Arkansas	<i>No Answer</i>					<i>No Answer</i>						<i>No Answer</i>			
Colorado	X					X	X		X			X			
Connecticut				X		<i>No Answer</i>						<i>No Answer</i>			
Delaware	X					X	X	X	X			X			
Florida	X					X			X			X			
Georgia	X					X	X	X	X				X		
Hawaii			X				X		X				X		
Illinois					B	X	X	X	X						F
Iowa					C	X	X	X	X						G
Kansas	<i>No Answer</i>					<i>No Answer</i>						<i>No Answer</i>			
Kentucky	X										X			X	
Maine	X							X	X					X	
Maryland	X					X	X	X	X						H
Michigan	X					X	X	X	X			X			
Minnesota	X					X	X	X	X			X			
Missouri			X				X	X	X						I
Nevada	X					X	X		X				X		
New Hampshire	X					X	X	X	X			X			
New Jersey	X					X	X	X	X			X			
North Carolina			X			X	X	X	X				X		
North Dakota			X								X			X	
Ohio			X						X					X	
Oklahoma			X				X	X	X					X	
Oregon			X			X	X	X	X						J
Pennsylvania					D	<i>No Answer</i>						<i>No Answer</i>			
South Dakota	X					X	X		X						L
Tennessee			X			X	X	X	X						M
Texas	X										X			X	
Utah	X						X							X	N
Vermont	X					X	X	X	X			X			O
Virginia	X					X	X	X	X			X			
Washington	X					X	X	X	X			X			P
West Virginia	<i>No Answer</i>					<i>No Answer</i>						<i>No Answer</i>			

Table G.2: Project Development Process (continued)

A: Currently developing a more formal process.

B: Depends on location of work, if ITS infrastructure is in place or if ITS expansion is planned at the location.

C: Involvement is growing at the concept level, especially when considering lane restrictions on the interstate, and likely traffic backups.

D: Varies across the state. We are working to better define the role.

E: Currently ad hoc but looking into this. Looking at stand-alone TSM&O projects but will be looking into the programing aspects as well as vs traditional state DOT means.

F: Any TSM&O review of projects is typically limited only to projects in areas of heavy traffic congestion.

G: Just starting to look at these issues.

H: Till now, this happens on a project by project basis. But this business process is being mainstreamed/ formalized through our upcoming SHA TSM&O Strategic Implementation Plan.

I: Sometimes. Usually when the project manager seeks out assistance.

J: Sometimes. It really depends on the project.

K: Varies across the state.

L: In some cases.

M: We are in the development stages of formalizing this review.

N: Not usually. Operations gets involved to evaluate traffic impacts of construction and provides insights on maintenance of traffic alternatives.

O: We do, but TSMO is still very new in Vermont, so this isn't 100% consistent.

P: Traditionally yes but with limitations - this is currently an agency focus area.

Table G.3: Process Guidelines

State	How much is TSM&O covered in design process guidelines, such as in planning guidelines, design manuals, etc.?					Does your agency have guidelines stating how TSM&O should be incorporated in the project development process prior to Operations?				Does your agency have any literature or case studies showing how TSM&O was incorporated in current or previous projects, outside of M&O projects?			
	A great deal	A lot	Moderate amount	A little	None at all	Yes	No	Not sure	Other	Yes	No	I don't know	Other
Alabama					X		X				X		
Alaska					X		X				X		
Arizona				X			X				X		
Arkansas	<i>No Answer</i>					<i>No Answer</i>				<i>No Answer</i>			
Colorado		X					X				X		
Connecticut	<i>No Answer</i>					<i>No Answer</i>				<i>No Answer</i>			
Delaware		X					X						F
Florida			X					X			X		
Georgia				X			X				X		
Hawaii				X			X				X		
Illinois				X			X				X		
Iowa				X			X						G
Kansas	<i>No Answer</i>					<i>No Answer</i>				<i>No Answer</i>			
Kentucky				X			X				X		
Maine			X				X				X		
Maryland			X						A				H
Michigan				X			X				X		
Minnesota			X				X				X		I
Missouri			X				X				X		
Nevada					X		X				X		
New Hampshire		X					X				X		
New Jersey	X						X				X		
North Carolina				X			X						J
North Dakota					X		X				X		
Ohio					X		X				X		
Oklahoma					X		X				X		
Oregon		X					X				X		
Pennsylvania				X			X				X		
South Dakota				X			X				X		
Tennessee				X					B		X		
Texas					X		X				X		
Utah			X						C		X		
Vermont		X							D		X		
Virginia			X				X				X		
Washington				X					E		X		
West Virginia	<i>No Answer</i>					<i>No Answer</i>				<i>No Answer</i>			

Table G.3: Process Guidelines (continued)

- A: For last few years, a TSM&O alternative has been made part of all major planning studies. This practice is being mainstreamed/ formalized through our upcoming SHA TSM&O Strategic Implementation Plan.
- B: In development.
- C: Yes, but mostly related to ITS elements. The planning and design process has steps where ITS should be engaged to provide input. Some designers "decide" that they don't need ITS and skip those steps.
- D: Sort of - we have a TSMO implementation plan, and this is laid out in that implementation plan.
- E: This is currently an agency focus area; F: Every capital transportation project is reviewed at all stages to include TSM&O as warranted.
- G: We have successfully used TIM planning and various ITS strategies on targeted construction projects for 4 construction seasons.
- H: For last few years, TSM&O alternative/ components has been made part of all major projects. This practice is being mainstreamed/ formalized through our upcoming SHA TSM&O Strategic Implementation Plan.
- I: We have some studies completed of the I-35W MnPass project.
- J: Have included ITS devices in projects.

Table G.4: Implementation Challenges

State	What are some of the challenges that you have encountered regarding the implementation of TSM&O in the project development process?							
	Business Process	Culture/Awareness/Understanding	Integration	Workforce	Budgetary	Consideration	Coordination	Guidelines
Alabama	X	X		X				
Alaska					X			
Arizona	X				X	X		X
Arkansas	<i>No Answer</i>							
Colorado			X			X		
Connecticut								
Delaware	<i>No Answer</i>							
Florida								
Georgia		X				X		
Hawaii				X				
Illinois	<i>No Answer</i>							
Iowa		X	X					
Kansas	<i>No Answer</i>							
Kentucky		X						
Maine		X				X		
Maryland		X	X					
Michigan		X	X					
Minnesota					X		X	
Missouri		X			X		X	
Nevada		X						
New Hampshire		X						
New Jersey		X				X		
North Carolina		X		X	X			
North Dakota	<i>No Answer</i>							
Ohio		X						X
Oklahoma					X		X	
Oregon					X			
Pennsylvania					X		X	
South Dakota			X					
Tennessee		X	X					
Texas								X
Utah		X				X		
Vermont		X	X					
Virginia							X	
Washington		X		X				
West Virginia	<i>No Answer</i>							

Table G.5: Capability Maturity Model (CMM) – Business, System & Technology

State	Does your agency utilize the Capability Maturity Model (CMM) framework to help improve the effectiveness of TSM&O activities?				For each of the Capability Maturity Model (CMM) Dimension, please select the appropriate capability level your agency is currently operating within the TSM&O program.									
					CMM Dimension: Business Processes (Planning, Programming, Budgeting, and Implementation)					CMM Dimension: Systems & Technology (Systems Engineering, Standards, and Technology Interoperability)				
	Yes	No	Not sure	Other	Level 1	Level 2	Level 3	Level 4	Not sure	Level 1	Level 2	Level 3	Level 4	Not sure
Alabama	X				X						X			
Alaska		X								X				
Arizona	X					X					X			
Arkansas			No Answer		X					X				
Colorado	X					X					X			
Connecticut		X								X				X
Delaware		X						X					X	
Florida	X						X					X		
Georgia	X					X						X		
Hawaii		X			X						X			
Illinois		X								X				X
Iowa	X					X				X				
Kansas			No Answer				No Answer				No Answer			
Kentucky		X			X					X				
Maine		X								X				X
Maryland	X						X					X		
Michigan				A		X					X			
Minnesota				B		X						X		
Missouri	X					X					X			
Nevada	X				X						X			
New Hampshire	X						X				X			
New Jersey		X			X							X		
North Carolina	X				X							X		
North Dakota		X					No Answer				No Answer			
Ohio		X			X						X			
Oklahoma		X			X						X			
Oregon	X						X					X		
Pennsylvania				C	X						X			
South Dakota	X				X						X			
Tennessee	X					X					X			
Texas		X								X				X
Utah				D		X							X	
Vermont	X									X				X
Virginia				E			X				X			
Washington	X						X					X		
West Virginia			No Answer				No Answer				No Answer			

Table G.5: Capability Maturity Model (CMM) – Business, System & Technology (continued)

- A: We have had two CMM workshops on the general concept of how to implement TSMO in the organization.
- B: Just beginning to do this with our TSMO Leadership Team.
- C: We completed the self-assessment. The TSMO Program Plan will identify what needs to be done to move up the CMM.
- D: Yes, but not in a formal way.
- E: We completed CMM in 2007 to standup organization and recently for Work Zones.

Table G.6: Capability Maturity Model (CMM) – Performance Measurement, Culture

State	For each of the Capability Maturity Model (CMM) Dimension, please select the appropriate capability level your agency is currently operating within the TSM&O program.									
	CMM Dimension: Performance Measurement (Measures, Data & Analytics, and Utilization)					CMM Dimension: Culture (Technical Understanding, Leadership, Outreach, and Program Authority)				
	Level 1	Level 2	Level 3	Level 4	Not sure	Level 1	Level 2	Level 3	Level 4	Not sure
Alabama		X				X				
Alaska	X					X				
Arizona		X						X		
Arkansas	X					X				
Colorado		X				X				
Connecticut					X					X
Delaware				X					X	
Florida		X							X	
Georgia			X				X			
Hawaii	X					X				
Illinois					X	X				
Iowa		X						X		
Kansas	No Answer					No Answer				
Kentucky	X					X				
Maine					X					X
Maryland				X			X			
Michigan		X					X			
Minnesota		X					X			
Missouri			X			X				
Nevada	X					X				
New Hampshire		X						X		
New Jersey			X				X			
North Carolina		X				X				
North Dakota	No Answer					No Answer				
Ohio	X					X				
Oklahoma	X					X				
Oregon		X						X		
Pennsylvania	X					X				
South Dakota	X						X			
Tennessee		X					X			
Texas					X					X
Utah			X					X		
Vermont					X					X
Virginia				X				X		
Washington			X					X		
West Virginia	No Answer					No Answer				

Table G.7: Capability Maturity Model (CMM) – Organization/Workforce, Collaboration

State	For each of the Capability Maturity Model (CMM) Dimension, please select the appropriate capability level your agency is currently operating within the TSM&O program.									
	CMM Dimension: Organization/Workforce (Organizational Structure and Workforce Capability Development)					CMM Dimension: Collaboration (Partnerships among Levels of Government and with Public Safety Agencies and Private Sector)				
	Level 1	Level 2	Level 3	Level 4	Not sure	Level 1	Level 2	Level 3	Level 4	Not sure
Alabama	X					X				
Alaska	X					X				
Arizona			X				X			
Arkansas	X					X				
Colorado			X				X			
Connecticut					X					X
Delaware			X						X	
Florida			X					X		
Georgia		X					X			
Hawaii	X					X				
Illinois					X			X		
Iowa		X					X			
Kansas	No Answer					No Answer				
Kentucky	X						X			
Maine					X					X
Maryland			X					X		
Michigan		X						X		
Minnesota		X							X	
Missouri		X					X			
Nevada	X					X				
New Hampshire			X						X	
New Jersey	X							X		
North Carolina		X					X			
North Dakota	No Answer					No Answer				
Ohio	X					X				
Oklahoma	X					X				
Oregon		X						X		
Pennsylvania		X				X				
South Dakota	X						X			
Tennessee			X					X		
Texas					X					X
Utah		X					X			
Vermont					X					X
Virginia			X						X	
Washington			X				X			
West Virginia	No Answer					No Answer				

APPENDIX H: State DOT Survey – Part II Responses

Table H.1: Project Delivery Systems

State	Project Delivery Systems: These refer to the overall processes by which a project is designed, constructed, and/or maintained). Please list example project types for all the project delivery systems currently being used by your agency.							
	Design-Build	Design-Bid-Build	Design Sequencing	Indefinite Delivery/ Indefinite Quantity (ID/IQ)	Agency-Construction Manager	Construction Manager at-Risk	Contract Maintenance	Other
Alabama	N/A	N/A	A	N/A	A	N/A	B	
Alaska	No Answer							
Arizona	C	C				C	C	
Arkansas	No Answer							
Colorado	D	E					F	
Connecticut	No Answer							
Delaware	No Answer							
Florida	No Answer							
Georgia	G	H	None	I	None	None	J	
Hawaii	K	L	M	N			O	
Illinois		P	Q					
Iowa					R		R	
Kansas	No Answer							
Kentucky	No Answer							
Maine	No Answer							
Maryland	S	T	U			Sometimes	V	W
Michigan	No Answer							
Minnesota	X	Y		Z				
Missouri	AA	AB	AC	AC	AC	AC	AD	
Nevada	AE	AF	No	No	No	AG	AH	
New Hampshire	AI	AJ	AK				AL	
New Jersey	No Answer							
North Carolina	AM	AN	AO	AP	AQ	AR	AS	
North Dakota		AT						
Ohio				AU			AV	
Oklahoma		AW						
Oregon								AX
Pennsylvania							AY	AZ
South Dakota							BA	
Tennessee	BB	BC	BD	BE		BF	BG	
Texas	BH				BI		BJ	
Utah	BK	BL		BM				
Vermont	BN	BO					BP	
Virginia	BQ	BR	Not familiar.	No	No	No	BS	BT
Washington	No Answer							
West Virginia	No Answer							

Table H.1: Project Delivery Systems (continued)

- A: Historical AASHTO methods.
- B: Used to supplement existing labor forces or to remove internal labor forces from hazardous environments (i.e., high speed-high volume).
- C: Delivery method used on projects in AZ.
- D: Interstate Managed Lane program with dynamic tolling.
- E: Device additions to existing roadways.
- F: US Highway 36 Managed Lane Program.
- G: Large capacity projects, Weigh-in-motion, new technology solutions.
- H: Large capacity projects.
- I: Maintenance, Operations, Design.
- J: ITS, Traffic Signals, Roadside maintenance, striping, resurfacing, signal operations, 511 operations, incident management, bridge and structure inspection.
- K: Roadway Improvements.
- L: All types of projects.
- M: New roads and roadway widening.
- N: Maintenance and ITS equipment.
- O: Grass mowing.
- P: Vast majority of construction projects utilize this sequence.
- Q: Larger projects may be issued as design-bid-build in sequence.
- R: All deployed ITS devices.
- S: Most projects fall in this category.
- T: Past projects were developed using this...fewer applications today.
- U: Complex projects only.
- V: Area wide maintenance contracts.
- W: Progressive design build recently being pursued.
- X: Many, I-494 Eden Prairie, TH 212, I-35W Bridge, TH 52 Rochester.
- Y: Typically done this way. MnDOT has an ITS Design Team. We do contract out some of this work.
- Z: Rural Intersection Conflict Warning System.
- AA: ITS and TSM&O strategies employed as part of a traditional construction project.
- AB: Installation of ITS devices, ITS device maintenance, ITS and TSM&O strategies employed as part of a traditional construction project.
- AC: Not used for TSM&O and ITS projects.
- AD: ITS device maintenance.
- AE: Major projects with short timeframes often use DB. The department is limited to the number of DB projects advertised each year.
- AF: The majority of projects are awarded using this process. This includes 3R, capacity projects, safety projects, etc.
- AG: The department uses CMAR for time-restricted projects that are generally smaller than the DB projects.
- AH: We have ITS maintenance contracts to augment staff at the district level.
- AI: Everett Turnpike ITS Corridor Deployment.
- AJ: Manchester to Concord Fiber Optic Installation.
- AK: Salem to Manchester - ITS Mainstreamed projects.
- AL: ITS Device Maintenance Contracts.
- AM: Mostly Interstate, approximately 20 currently.

Table H.1: Project Delivery Systems (continued)

AN: These are the majority of our projects.
AO: Some of the Design Build projects are done this way.
AP: Purchase Order contracts for equipment.
AQ: We have one project with a Travel Demand Manager requirement just for traffic operations.
AR: On call services are available, especially for our toll projects.
AS: Yes, especially for maintenance of devices. None are performance based.
AT: All ITS projects stand alone and ITS incorporated in typical projects.
AU: ITS Maintenance project coming soon.
AV: ITS Device Maintenance Contracts.
AW: 95 % of the time.
AX: I'm not sure I understand what you are looking for. We primarily utilize Design-Bid-Build for operations projects; although there have been a few projects.
AY: ITS maintenance contracts.
AZ: I'm not familiar enough with our contracting methods. I believe we use both DB and DBB.
BA: Some ITS Infrastructure Maintenance.
BB: Design-Build has been utilized on Interstate Widening Projects.
BC: The Majority of Projects are still Design-Bid-Build, even ITS.
BD: ITS Projects have been divided into phased design deployments.
BE: This has mostly been used on the Software & Hardware side with our IT Division.
BF: CMGC has been used for major bridge work projects in heavily congested urban areas.
BG: We use maintenance contracts for ITS devices in the field. Such maintenance contracts are also utilized for by TDOT Maintenance.
BH: Toll roads, expressway construction.
BI: Roadway construction, traffic operations construction (signals, ITS, signing & pavement marking).
BJ: Roadway maintenance, Traffic system maintenance (signals, ITS, signing & pavement marking).
BK: Traffic signals, simple ITS devices.
BL: Traffic signals, ITS devices, fiber network.
BM: Traffic signals, ITS devices, signal and ITS maintenance.
BN: Bridge
BO: Bridge, Highway.
BP: Culvert, Rail, Line Striping.
BQ: I-66 Active Traffic Mgt, I-77 Active Traffic/Safety Mgt, and I-64 ATSM.
BR: ITS Civil Construction, new signals.
BS: Contract through non-professional services good and services procurement for SSP, TOC and ITS Maintenance services at statewide level.
BT: We have professional design services for ITS design and CEI contracts.

Table H.2: Design-Build Project Delivery System

State	If your agency uses Design-Build project delivery system, does it include any of the following: Select all that apply.					
	Design-Build-Warranty	Design-Build-Maintain	Design-Build-Operate	Design-Build-Operate-Maintain	We don't use Design-Build systems	Not sure
Alabama					Yes	
Alaska						Yes
Arizona				Yes		
Arkansas	<i>No Answer</i>					
Colorado	Yes	Yes	Yes	Yes		
Connecticut						Yes
Delaware						Yes
Florida			Yes	Yes		
Georgia	Yes	Yes	Yes	Yes		
Hawaii	Yes					
Illinois						Yes
Iowa					Yes	
Kansas	<i>No Answer</i>					
Kentucky						Yes
Maine						Yes
Maryland	Yes					
Michigan					Yes	
Minnesota	Yes		Yes			
Missouri	Yes					
Nevada	Yes					
New	Yes	Yes				
New Jersey		Yes				
North Carolina	Yes	Yes	Yes	Yes		
North Dakota	<i>No Answer</i>					
Ohio					Yes	
Oklahoma					Yes	
Oregon					Yes	
Pennsylvania						Yes
South Dakota	<i>No Answer</i>					
Tennessee						Yes
Texas	Yes			Yes		
Utah	Yes					
Vermont						Yes
Virginia	Yes	Yes	Yes			
Washington	Yes					
West Virginia						

Table H.3: Procurement Practices

State	Procurement Practices: These are the procedures agencies use to evaluate and select designers, contractors, and various consultants. Please list example project types for all the procurement practices currently being used by your agency.								
	Cost-Plus-Time Bidding (A+B)	Multi-Parameter Bidding (A+B+C)	Lump sum Bidding	Alternate Design	Alternate Bid	Additive Alternates	Best-Value Procurement	Bid Averaging	Other
Alabama	A	N/A	B	C	N/A	D	E	N/A	
Alaska	No Answer								
Arizona	F		F						
Arkansas	No Answer								
Colorado									G
Connecticut	No Answer								
Delaware	No Answer								
Florida	No Answer								
Georgia	H	H	I				J		
Hawaii	No Answer								
Illinois									K
Iowa									L
Kansas	No Answer								
Kentucky	No Answer								
Maine	No Answer								
Maryland	No Answer								
Michigan									M
Minnesota	No Answer								
Missouri	N	N	N	N	N	O	N	N	
Nevada	No Answer								
New							P		
New Jersey	No Answer								
North	No Answer								
North	No Answer								
Ohio	No Answer								
Oklahoma	No Answer								
Oregon			Q				R		
Pennsylvania									Unsure
South	No Answer								
Tennessee									S
Texas	T		U	V	V		W		
Utah	X					Y			
Vermont	Z			AA					AB
Virginia	Yes		Yes	No	No		AC		
Washington	No Answer								
West	No Answer								

Table H.3: Procurement Practices (continued)

- A: Turn key solutions.
- B: Emergency repairs and turn key solutions.
- C: High profile projects only.
- D: Land and Building improvements.
- E: Technology solutions.
- F: Procurement method used.
- G: Not sure on the selection process.
- H: Operations, Design, Maintenance.
- I: Operations, Design, Maintenance, Planning.
- J: Weigh-in-motion installation.
- K: Vast majority of projects are awarded to low bidder.
- L: We use multiple methods.
- M: Competitive bidding/low bid process.
- N: Not used for TSM&O and ITS projects.
- O: Attempted to use, but project manager would not allow due to his belief that it did not exactly match the original scope.
- P: Everett Turnpike ITS Corridor Project.
- Q: Many of our software projects are lump sum. Construction is usually a combination of lump sum and quantity based items.
- R: Approach use for most of our equipment procurement contracts.
- S: We primarily use a Qualification Based Selection for engineering services contracts.
- T: Professional Services (Architecture, Engineering, Surveying).
- U: Professional Services (Architecture, Engineering, Surveying).
- V: Roadway construction.
- W: Non-Architecture, Engineering, Surveying) Professional Services.
- X: ITS projects - VMS, cameras, etc., including fiber.
- Y: ITS projects.
- Z: I know we do this, but not sure about what types of projects.
- AA: Bridge.
- AB: Low Bid: Mostly all of our contracts.
- AC: Yes, most goods and services contract (SSP, TOC, ITS Maintenance, 511, etc.).

Table H.4: Contract Management Methods

State	Contract Management Methods: These refer to the procedures and contract provisions used to manage construction projects on a daily basis to ensure control of costs, timely completion, and quality of construction. Please list example project types for all the contract management methods currently being used by your agency.						
	Incentives/Disincentives (I/D) Provisions for Early Completion	Lane Rental	Flexible Notice to Proceed Dates	Liquidated Savings	Active Management Payment Mechanism (AMPM)	No Excuse Incentives	Other
Alabama	A	N/A	B	N/A	N/A	N/A	
Alaska	No Answer						
Arizona	C						
Arkansas	No Answer						
Colorado	D						
Connecticut	No Answer						
Delaware	No Answer						
Florida	No Answer						
Georgia	E						
Hawaii	No Answer						
Illinois	F						
Iowa							G
Kansas	No Answer						
Kentucky	No Answer						
Maine	No Answer						
Maryland	No Answer						
Michigan	No Answer						
Minnesota	No Answer						
Missouri	H	I	H	H	I	I	J
Nevada	No Answer						
New	No Answer						
New Jersey	No Answer						
North Carolina	No Answer						
North Dakota	No Answer						
Ohio	No Answer						
Oklahoma	K	K	K				
Oregon	No Answer						
Pennsylvania							Unsure
South Dakota	No Answer						
Tennessee	L						
Texas	M	M					
Utah	N	N					
Vermont	O						
Virginia	P	Q	R	No		Yes	
Washington	No Answer						
West Virginia	No Answer						

Table H.4: Contract Management Methods (continued)

A: Emergency repair, high profile road or bridge construction.

B: Asphalt/Concrete work let out of season.

C: Procurement method used.

D: Emergency road repairs for critical highway closures.

E: Most contracts.

F: Urgent or high-profile projects may use this method.

G: We use multiple methods.

H: Done as part of Design-Build and Design-Bid-Build.

I: Not used for TSM&O and ITS projects.

J: Liquidated damages is the most often used tool at MoDOT.

K: Yes, project by project basis.

L: This is the typical contract management process used for construction projects by TDOT.

M: Roadway construction.

N: Used for road construction projects that have ITS elements, but are generally not used for ITS-only projects.

O: Highway, Bridge.

P: Yes, most projects.

Q: Few projects.

R: Paving Schedules.

Table H.5: Funding Sources Used for TSM&O Activities

State	What funding sources are used for TSM&O activities by your agency? Select all that apply.									
	Congestion Mitigation and Air Quality Improvement (CMAQ) Program	Surface Transportation Program (STP)	Highway Safety Improvement Program (HSIP)	National Highway Performance Program (NHPP)	Transportation Investment Generating Economic Recovery (TIGER)	Highway User Revenue Fund	Local Taxes	Unified Planning Work Program (UPWP)	Public-Private Partnership	Other
Alabama	Yes	Yes	Yes		Yes					
Alaska										A
Arizona	Yes	Yes	Yes	Yes	Yes	Yes	Yes			
Arkansas	No Answer									
Colorado			Yes	Yes	Yes	Yes			Yes	
Connecticut	No Answer									
Delaware	Yes	Yes	Yes		Yes					
Florida	Yes	Yes	Yes		Yes				Yes	
Georgia	Yes	Yes				Yes	Yes		Yes	
Hawaii	No Answer									
Illinois	Yes	Yes				Yes				
Iowa	Yes						Yes			
Kansas	No Answer									
Kentucky	No Answer									
Maine							Yes			
Maryland	Yes	Yes	Yes	Yes						
Michigan	Yes	Yes								
Minnesota	Yes	Yes	Yes		Yes	Yes	Yes			
Missouri	Yes	Yes							Yes	
Nevada	Yes	Yes	Yes	Yes		Yes				
New Jersey	Yes	Yes	Yes							B
North Carolina	Yes	Yes	Yes				Yes			C
North Dakota	No Answer									
Ohio			Yes		Yes				Yes	
Oklahoma		Yes	Yes							
Oregon	Yes	Yes			Yes		Yes	Yes		
Pennsylvania	Yes	Yes		Yes						D
South Dakota		Yes	Yes	Yes			Yes			
Tennessee	Yes	Yes	Yes	Yes						
Texas										E
Utah	Yes						Yes			F
Vermont										D
Virginia	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Washington	Yes	Yes	Yes		Yes	Yes			Yes	
West Virginia	No Answer									

Table H.5: Funding Sources Used for TSM&O Activities (continued)

A: No funding at this time.

B: State Budget.

C: Highway Fund uses gas tax.

D: State funds/funding.

E: None at this time.

F: Road construction projects use many of these other methods, and may have ITS/Operations components in them, but ITS-only projects are usually CMAQ or state funds.

Table H.6: Funding and System Development Strategies

State	Please identify the strategies used by your agency to fund TSM&O projects.				Which system development strategy (i.e., model) does your agency adopt for TSM&O and ITS projects. Select all that apply.				
	We set aside dedicated funding for TSM&O projects	We allow TSM&O projects to compete with other types of projects for funding	We combine a set-aside with the ability for TSM&O projects to compete for other funding	Other	Waterfall Model	Agile Model	Incremental Build Model	Spiral Model	Other
Alabama				A	Yes				
Alaska				B	No Answer				
Arizona		Yes			Yes				
Arkansas	No Answer				No Answer				
Colorado			Yes						Not Sure
Connecticut	No Answer				No Answer				
Delaware				C	No Answer				
Florida		Yes			No Answer				
Georgia	Yes						Yes		
Hawaii	No Answer				No Answer				
Illinois	Yes				Yes				
Iowa			Yes						Other
Kansas	No Answer				No Answer				
Kentucky				D	No Answer				
Maine				E	No Answer				
Maryland			Yes		No Answer				
Michigan				F	No Answer				
Minnesota			Yes		Yes				G
Missouri			Yes				Yes		
Nevada	Yes								H
New	Yes				Yes		Yes		
New Jersey	Yes				No Answer				
North				I	Yes	Yes			
North Dakota	No Answer				No Answer				
Ohio			Yes			Yes			
Oklahoma		Yes			Yes				
Oregon			Yes				Yes		
Pennsylvania				J					Unsure
South Dakota			Yes		Yes		Yes		
Tennessee			Yes		Yes	Yes			
Texas				K			Yes		
Utah	Yes				Yes	Yes			
Vermont	No Answer				No Answer				
Virginia	Yes								L
Washington			Yes		No Answer				
West Virginia			Yes		No Answer				

Table H.6: Funding and System Development Strategies (continued)

- A: RTMC and Service Patrol operations are funded annually within the routine maintenance budget. Most projects are sublet under other funding sources.
- B: No funding at this time.
- C: All projects a reviewed for the addition of TSM&O and costs for TSM&O are included in the project where warranted.
- D: We are struggling to maintain the existing ITS assets.
- E: Have not specifically built a TSM&O project.
- F: ITS project set aside funding and blend in ITS strategies with capital improvement projects.
- G: Not sure, but I believe it is Waterfall Model.
- H: We do not have a specified model.
- I: New devices compete with other projects. O&M are funding with state funds.
- J: Projects are funded by planning partners as well as State dollars in our statewide budgets.
- K: None at this time.
- L: For ATMS we use milestones with sprints in between. Other projects probably use waterfall.

APPENDIX I: District Survey – Project Development Methods

Sample Survey Questionnaire – Project Development Methods

Dear Mr. Chen:

The University of North Florida, Florida International University, and Hagen Consulting Services are working on a research project BDV34 977-07 **Evaluation of Project Processes in Relation to Transportation Systems Management and Operations (TSM&O)**. The objective of this project is to review and evaluate different processes related to TSM&O projects to better accommodate TSM&O in the project development process. TSM&O projects are performance-based and as a result are increasingly software-based because of the quantity of data that is required to be collected and analyzed. The public agencies managing these TSM&O projects have adopted traditional project development approaches used for most civil engineering projects and consistently run into challenges related to procurement time, resulting in a product that is not what the agency expected or a product that is already obsolete. Agencies realize that these processes are limiting TSM&O project development but at this current time, policy and/or staff knowledge on other processes do not allow for an alternative approach.

As part of this research project, we want to review the current project development method used by FDOT for TSM&O projects, specifically for Intelligent Transportation Systems (ITS) and Advanced Traffic Management System (ATMS) projects. We are especially interested in obtaining information on specific challenges and shortfalls of the current project development process undertaken at the district and state level. To accomplish this task, we have designed a questionnaire survey and we plan to interview at least one project manager from the FDOT Central Office, and at least one project manager from each FDOT Districts who has overseen at least one ITS/ATMS/TSM&O software development project. Since you have been involved with the **Maintenance Information Management System (MIMS)** software development project, we appreciate if you could please answer the following questions.

If you have any questions or comments about this survey, please feel free to contact:

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Note that the questions are divided into three sections: Project Overview, Project Requirements, and Project Implementation.

Please answer all the questions. In cases where questions are not applicable, please write "NA" in the space provided.

Project Overview

In this section, the questions focus on the project objective, the project team, and the project delivery system used in the MIMS project. There are seven questions in this section.

Question # 1: What was the objective of the MIMS project that you were recently involved in?

Question # 2: What was your role in this project? Could you please elaborate on your responsibilities in this project?

Question # 3: Who else from the state or the district level were involved in the project?

Question # 4: Was the project objective clear to everyone involved in the project?

Question # 5: Did you feel that if some other personnel could provide valuable inputs and, therefore, should have been involved in the software development process?

Question # 6: Which delivery system (e.g., design-build, design-bid-build, design sequencing) was used for this project?

Question # 7: Did you feel that the project could be benefitted more if a different delivery process was undertaken?

This is the end of the *Project Overview* section.

Project Requirements

Typically, several project requirements are set at the beginning of the project and the project is carried out to meet those requirements. The project development process is usually sequential, meaning the next step is not initiated until current step is completed. Generally, the steps include requirements analysis, design, code, integration, test, and deploy. However, in some situations it is inevitable that the project requirements need to change, which might impact the overall project in terms of cost effectiveness and on-time delivery of the project. We set several questions related to the project development process used in the project and the challenges involved in meeting the project requirements. There are a total of 11 questions in this section (Question #s: 8 - 18).

Question # 8: What were specific requirements of this project related to software development or updates?

Question # 9: Did the development team ask for any clarifications on the requirements? In other words, did you feel that the requirements were well understood by the development team up-front?

Question # 10: Did the software development or updates follow the *Systems Engineering Process* (e.g., Vee Development Model)?

Question # 11: Did any changes (e.g., modifications or additions) in project requirements occur midway of the project? If yes, then please answer the following questions:

- (a) Who first did feel the need for this change and at which stage of the project?
- (b) Who were responsible to make the changes happen?
- (c) What was the impact of the change(s) on other steps of the project?

Question # 12: Do you think that some other requirements could be added to the project at the time the projects reached the testing phase?

Question # 13: How much time was spent in the testing stage to ensure that the product met the requirements?

Question # 14: Who was responsible for the testing?

Question # 15: What evaluation criteria were used for testing?

Question # 16: Were the criteria sufficiently performance-based?

Question # 17: Did you feel that any other evaluation criteria could also be used?

Question # 18: Did you know whether the product (i.e., software) kept provisions to incorporate future technical innovation?

This is the end of the *Project Requirements* section.

Project Implementation

This section focuses on the project duration and flow, project meetings, team members' communications, and your view on how to improve managing a software development project. There are a total of 12 questions in this section (Question #s: 19 - 30).

Question # 19: What was the planned duration of this project? Was it a high-risk project?

Question # 20: Was the project delivered on time according to schedule? If not, what do you think the main reasons behind the delay?

Question # 21: Did the development team inform about the progress at regular intervals?

Question # 22: Did you feel you were always kept informed of the progress?

Question # 23: How many meetings were held over the project span from planning to delivery?

Question # 24: Were the meetings pre-scheduled as in the project contract or on-demand?

Question # 25: At what frequency were the meetings held?

Question # 26: Who usually were present during the meetings?

Question # 27: Did you feel the project went smoothly?

Question # 28: What were the specific impediments faced by the project team during the implementation of the project objective?

Question # 29: What steps you consider could have been taken to improve the project and optimize benefits from the project?

Question # 30: What do you consider as being the lessons learned in this project?

Thank you very much for your time.